TIGHT BINDING BOOK

# ★ Minerals of Might

By William O. Hotchkiss

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With a prayer that they may know no other war
I dedicate this to my grandchildren
Ann, Julie, Kay Chadbourne, Bill, Lee Christine,
Henry, Tommy, and Georgia Edith.

# PREFACE

AT THE birth of this country our forefathers lived in essentially the same manner as men in ancient times. Their food was grown by methods and with implements like those of the Romans. Their clothing was spun and woven as Penelope made her web for Odysseus. Transportation was by sailing boats and crude, animal drawn, wheeled vehicles like those familiar to the Egyptians and Assyrians. Their communications were by messenger, afoot or mounted.

The more we know about the modes of living and working at the time of the American Revolution the greater seems the marvel of the present. The better we understand the causes of that almost unbelievable transformation, from then to now, the more capable we shall be of cherishing and perpetuating the conditions that have given us what we have.

Almost the whole *material* difference between then and now is the use we make of natural resources. The use of minerals by the nations of the world has increased so greatly that in the last thirty years we have used approximately as much as man had used in all previous history. Few of the useful minerals are inexhaustible. Some of them are being used at a rate that will exhaust the supply in a few decades.

When we consider the part that steel, oil, coal, aluminum, copper, lead, zinc and a host of lesser minerals have played in the success of our armed forces in this war it is wise to be aware of what the future holds for us in supply of these minerals of might. If he knows the facts, no good citizen will say smugly "What of it, when our steel is gone some scientist will find a substitute."

This book is a contribution to the understanding of the non-technical person who wants the facts about our mineral resources told briefly and intelligibly, and in proper perspective.

The statistical data are taken from standard sources such as the *Minerals Yearbook* of the U. S. Bureau of Mines, and the *American Petroleum Institute Quarterly*. Special thanks are due to the McGraw Hill Publishing Company for permission to quote from *Man and Metals* by T. A. Rickard, to the Brookings Institution for permission to quote from *World Minerals and World Peace* by C. K. Leith, J. W. Furness and Cleona Lewis; to the Kansas University Press for permission to quote from *Oil in the Earth* by Wallace Pratt, and to Charles M. Parker for permission to quote from *Steel in Action*. I am much indebted to R. C. Allen, Donald B. Gillies, C. K. Leith, and Warren S. Blauvelt, and to my wife and daughter, all of whom read the manuscript and made many helpful suggestions.

WILLIAM O. HOTCHKISS

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# CHAPTER 1

## What Are Natural Resources

I WAS sitting on the deck of the big iron ore freighter enjoying a beautiful bright morning. We had just left Ashtabula for a trip up the lakes to Duluth and back. The five men who had invited me to accompany them were all old acquaintances and friends. The two high-school lads I had never met before. They were sons of the lawyer and the banker of the group and were just at that interesting age when boys begin to think seriously at times about the world ahead of them. We were discussing the latest news from the war and from Washington as men are doing all over the country wherever two or three are gathered together.

The men were all officers of one of the smaller steel companies. The president, who shall be called Mr. President, was semi-retired and was devoting much of his time to his pet farm. He seemed to take more pride in his farm and orchards than he did in his accomplishments in business. He delighted in visiting and talking with his neighbors who had been farmers all their lives. His human quality was attested by the fact that he had won their regard so that he was accepted as a friendly neighbor, and no longer looked at, as he had been at first, as merely a wealthy interloper into their neighborhood. It was further attested by the fact that there had never been labor trouble at the plants of the company in all the long years he had been president.

Mr. Lawyer, who had brought his son Bob along for the trip, was a director of the company and looked after its legal and tax affairs, an onerous duty in the current times. The

banker was a director of the company because of the financial interest of his father's estate. We will refer to him as Mr. Banker. His son, Dick, was the other high-school boy of the party.

The other two were men who from their early twenties had been employed by the company and had grown into chief management positions. They were active minded, good steel executives, the superintendent, Mr. Superintendent and the manager, Mr. Manager.

Our conversation on the war lagged after each of us had expressed his pet optimism or his pet pessimism as the case might be. I was sitting there just absorbing the beauty of the morning,—just sitting, not thinking—when Mr. President turned to me smilingly, and with the informality of old friendship said, "Hotchkiss, you may think we invited you along just because we like your company. We do, but we asked you to come because we want you to tell us some things on this trip. We have all of us been reading statements that this is a technical war, that it is a scientific war, that it is a war of metals, that it is a war of fuels, and so on. We know quite a bit about this, of course, from our side of the business. We got to talking about it a few weeks ago in the office and decided it would be very interesting to get a better rounded picture of the part that all our natural resources play in the war, and the part they will play in the after-war period. So we invited you to come along. After we decided to do this, Mr. Lawyer and Mr. Banker suggested that they bring Bob and Dick. I told them they could if Bob and Dick would promise to ask all the questions they could think of. So that's why you are here. We hope you don't object."

I smiled and replied, "I see you have shanghaied me and are going to make me work my passage. It is fortunate that I brought along the minerals yearbook, so we can have it to refer to. I also brought along *Man and Metals* by

T. A. Rickard, a pair of volumes I often refer to and enjoy reading, and a small volume entitled "World Minerals and World Peace" by C. K. Leith and others. So we will be well provided with reference material. But you knew all along that I should enjoy nothing more than talking about natural resources. I've spent too many years of my life studying them to find it an unpleasant chore to talk about them. I'll consent to do as you want if you will promise to make this a forum to which all of us contribute. If I got to lecturing, I might get too dry and technical. If I do, someone must break in with a question."

Mr. President, That's just what I want, and we'll all promise. Let's call it a forum on Natural Resources. Go ahead.

Mr. Hotchkiss: Well, let's get a common background to begin with. Bob, what would you say is the most important natural resource?

Bob: I'd say it was iron.

Mr. Hotchkiss: Dick, would you agree Bob is right?

Dick: Yes, I think he is.

Mr. Hotchkiss: Maybe we'd better make a list of the important natural resources. What would you name Mr. President?

Mr. President: I should certainly say that the soil that produces our food and clothing and timber for our houses was more important than iron.

Mr. Banker: I should put water ahead of the soil in importance. You can have the best of soil in a desert climate and it won't produce anything.

Mr. Lawyer: In my law studies I found that the fee ownership of property is supposed to extend from as deep below the surface as the owner cares to go to the highest point he wishes to build into the air, so air must be added to the list.

Mr. Banker: I agree, and I would put it at the top of the

list. If air were taken away from us we would all die in a few minutes. Yes, air is certainly a natural resource.

Mr. Hotchkiss: Bob, what would you say to adding the heat and light of the sun to the list?

Bob: I guess we'll have to. They would have to rank in importance with air and water. If some thick curtain were pulled between to shut us off from the sun, we would all freeze to death in a short time.

Mr. Hotchkiss: I see you have had a good physical geography teacher, Bob. You are lucky.

Mr. Manager: It seems to me we have wandered away from what we all think of when the subject of natural resources is mentioned. How about aluminum and magnesium, copper, lead, zinc, chrome, nickel, manganese? From the standpoint of the war they seem more important.

Mr. Superintendent: True. In all our thinking and the hard work we do in making steel for war, the metals play an important part. But I guess they wouldn't if we lacked the other things that have been named. There wouldn't be any war if we didn't have any air or water, or if there wasn't any soil to grow food, or if the sun didn't furnish heat and light. In fact, there wouldn't be any human beings alive to kill each other. Maybe this is just the background we need. Some of our natural resources are so abundant and so available everywhere that we have forgotten to think of them at all. We don't remember that they are natural resources. We have let our thinking dwell on those things that are scarce. We have thought of the less abundant, and less well distributed things like the metals so intensively that they are the only things we think of as natural resources. When Bob said iron was the most important natural resource, I thought he was right. I guess we'll have to agree with the rest, Bob.

Mr. Hotchkiss: Well, Dick, let's hear your latest revised definition of natural resources.

Dick, with a long breath: It's revised lately all right. I

guess I'd have to make a definition that would include all the things found in nature that human beings can use.

Mr. President: That's a fine definition, Dick. It's a better one than any of us had in mind when we started out.

Bob: It surprises me how simple it all sounds when you think it out. When natural resources were first mentioned, I said to myself, "That's where they go way over your head, young fellow." Now I shall not be scared again when anyone mentions natural resources. Dick's "latest revised definition" is good. I can name a lot of things that come under that. The stone that dad's bank is built of is a natural resource. The cement rock they mine near our farm is another. The gravel and sand they mixed with the cement to pave the road past our farm come under Dick's definition. The oil that I saw being pumped, the coal, the salt, the natural gas are natural resources just as definitely as the iron ore this boat will be loaded with at Duluth.

Mr. Hotchkiss: Having reached agreement on the definition of natural resources, it is worthwhile to mention that the material prosperity of the human race from its beginning has depended on three things:

1. Natural Resources
2. The brains, and
3. The energy which men have applied to making natural resources serve their needs and desires. Perhaps I should emphasize that I said 'material prosperity.' There are kinds of prosperity other than the material. I think that in the sense in which we are speaking, we could also speak of spiritual prosperity, and cultural prosperity. But I don't like that term cultural. It has been misused so much that I shy from it. The sense in which I like it best is exemplified by Matthew Arnold when he said, 'The great men of culture are those who have had a passion for diffusing, for making prevail, for carrying from one end of society to the other, the best knowledge, the best ideas of their times; who have labored to divest knowledge of all that was harsh, uncouth,

difficult, abstract, professional, exclusive; to humanize it, to make it efficient outside the clique of the cultivated and learned.' In this sense you steel men can include yourselves in the list of the cultured. The men who originated the modern methods of mining the iron ore we are going to Duluth to get contributed cultural factors of most significant value.

Too often the word culture is taken to include only art, literature, philosophy and science, with science not fully accepted. The great days of Greece are often cited as the highest peak of culture ever reached by man. Maybe they were, but this peak collapsed utterly because it was based on an insecure social foundation. It is not commonly known that the economic background that made possible the great era of Greek culture was a natural resource,—the wealth of the silver mines twenty-five miles from Athens down the Attic peninsula. These were worked by thousands of cruelly treated slaves. When the silver was exhausted Greek culture soon became a thing of the past.

Greek culture required the excess wealth that provided the leisure for its cultivation by certain few in the social structure. Without that leisure it could not live.

Another good example of the relation of culture and the use of natural resources can be found in our own country. When the white men came to America there were about as many Indians living here as there are today, probably about half a million in number. They had lived here for untold centuries. According to their mode of living there were about as many as the country could support. Today there are 135 million of us, each enjoying many more things, a much fuller material, spiritual and cultural life, than the individuals who made up the half million Indians of that day.

What is the difference between that day and now? The Indians are intelligent people, perhaps as intelligent as the white men, perhaps not. The difference is not so great that

all students are convinced that it exists. The chief difference is that the white men who came here had inherited much greater knowledge of how to use natural resources. The Indian made little use of the soil. The white man made great use of it. The use of other natural resources was practically unknown to the Indians. The white man knew much about how to use many of them. In this race, the white man had a running start and a long handicap. There could be no doubt concerning which of these would be the winner.

The Indian culture supported a half million or less in squalid poverty for the most part. The white man's culture in our country supports 135 millions of us in greater comfort and luxury than any equal number of humans ever knew. The outstanding difference in the two cultures is the use made of natural resources.

The future of the white man's culture in America, in the same way it has been determined in the past, will be determined in a most important degree by his use of natural resources.

Mr. President: Those are very interesting comparisons and give us much to think about. I wonder if it wouldn't be profitable to take up in some detail the development of the use of natural resources throughout the past.

Mr. Hotchkiss: If you like I shall be glad to do it. What do you say to confining our discussion to the things in which we personally are most interested as suggested a while back by Mr. Manager—what we may call the mineral resources, the geological resources, those things that are more limited in quantity and more restricted in their occurrence than soil and water and the other more common things.

Mr. Manager: I shall be glad to have you do that. This broad background we have been discussing is well worth while, but my personal interest is in the mineral resources. I would like to know more about how their use developed.

# CHAPTER 2

# Development of the Use of Natural Resources in War

MR. HOTCHKISS: In as much as we are to limit our discussions, to the development of the use of mineral resources, I suggest that we take up first the development of their use in war.

The metals are, of course, the resources that come first to our minds. Their use goes back beyond recorded history. We can only speculate on how they were first discovered, and we can only draw such inferences as seem sensible from the ancient relics the archeologists find when they dig about dwelling places of people long since no more.

Copper is easily melted and workable. Its ores were present in the areas where civilization first began to develop. Being a soft metal, poorly suited for use in sharp edged or pointed implements, its first use was undoubtedly for ornaments and utensils. Only after the discovery, first, that it could be hardened by hammering, and, second, of its alloy with tin, did men have a metal that was hard enough for war use. Only then did hammered copper and bronze begin to supersede effectively stone and horn for the points of weapons. Since bronze was scarce and costly its use became common only after a long period. Daggers and swords, war axes and spearheads were the chief metal implements of war. They were probably in use to some extent 5,000 or more years ago. Bronze continued to be the chief metal for war purposes down to 2,000 to 2,500 years ago.

Iron had probably been known nearly, if not quite, as far back as bronze. Its superiority over bronze was very evident. But the difficulty of reducing it from its ores was so great that men did not learn how to do it for a long time. The early iron was all from meteors and so was scarce, and the relatively cheaper and more available bronze outstripped it in use for a long time.

During much of the Bronze Age there were a few highly prized weapons of iron. They were the choice possessions of leaders and kings. Their superiority over bronze weapons was marked. As the supply of this precious iron accumulated slowly the number of weapons made from it increased. Parker, in *Steel in Action*, his interesting recent book, states that the army of Sargon II, who reigned in Assyria about 705 B.C., was the first large army to be completely equipped with iron weapons and that 'a single arsenal room . . . contained about 200 tons of iron implements.'

The present day advocates of the insurance of future peace by preventing the Germans and Japanese from getting natural resources for weapons and supplies of war are reviving one of the ancient methods. The other is referred to on p. 18. First Samuel, XIII, verse 19, reads, "Now there was no smith throughout all the land of Israel; for the Philistines said, 'Lest the Hebrews make them swords and spears.'" *Steel in Action* states: 'When Lars Porsena, the Etruscan king, conquered Rome in 507 B.C., one of the conditions of peace imposed was a prohibition of the use of iron except for agricultural purposes.'

Gold and silver played an important part in ancient wars. The campaigns of Alexander the Great were paid for in the beginning from the treasure his father, Phillip II, had accumulated from the then rich Macedonian placer gold deposits and silver mines. Later he had the treasure he captured to finance his operations.

Gold and silver were almost certainly the first metals

widely used. They are found in many places as native metal which does not require the smelting operations that all other metals require. Their "noble" qualities of scarcity and resistance to corrosion made them highly desirable for ornaments, which were traded widely. Common use as coins did not begin until about 600 B.C.

The part played by metals in war, chiefly iron and steel, increased slowly as the stocks of metals increased. There was relatively little change in the weapons of war from ancient times until gunpowder came into moderately effective use shortly before the discovery of America. Undoubtedly Caesar had more iron and steel for equipment of his armies than had Alexander three centuries earlier. Before the fall of Rome the supply of iron had increased still further. During the Crusades iron was plentiful enough to provide much armor.

In all this time, from the end of the Bronze Age to the middle of the 14th century, a period that endured for over 2,000 years in the more civilized countries, the use of iron for war had been chiefly as spears, swords, daggers and later as armor. Refinements in shape of weapons, in workmanship and in the quality of steel available had improved the quality of implements of war, but no other important difference developed.

When gunpowder and guns began to be used a great change was initiated. Fighting could be done at a distance. A foe with only hand weapons was at the mercy of an army with guns. It took a century of the use of gunpowder before artillery was developed to any really usable degree. Early cannon were more often than not cast of bronze, but advances in iron metallurgy soon permitted the casting of satisfactory iron cannon. Says *Steel in Action*. 'During the reign of Elizabeth (1558–1603) the trade became so prosperous that England began to export large quantities of iron in the form of ordnance. Some of the cannons cast in Sussex

weighed more than three tons. The exportation of cast iron cannon became so extensive that complaint was made that Spain was arming her ships with them to fight the ships of England, and the trade was prohibited.'

With the adoption of gunpowder as a war material, the use of iron for hand guns and cannon superseded the former uses for swords, axes, spears and armor. The quantity of steel and iron used for war purposes increased notably, both because larger and more numerous artillery pieces were used and because increased wealth and population permitted larger armies.

But still the use of iron and steel for military purposes was minutely small compared to the amount used today. It is probable that there was not more than 15 or 20 million tons of iron and steel in the world in use for all purposes when Napoleon conquered Europe. The estimated world production for the year 1,800, was only 800,000 tons compared to about 250 times that in recent years.

Mr. Superintendent: That seems incredible. Our plant, which is a small one in these days, produces more steel than was produced in all the world a hundred and fifty years ago.

Mr. Hotchkiss: It required the development of the Industrial Revolution to bring about the present tremendous use of iron and steel in war. This took three main forms, the development of the railroad, the development of the steel ship with steam propulsion, and the development of internal combustion engines, gasoline and diesel, and the rapid and more efficient land transport that this made possible.

Napoleon said an army moved on its belly. His army had to be fed, his supply trains were animal drawn and slow, and had little capacity. Napoleon could not have handled an army of three million men if he had had one. Nor could he have moved it about and kept it supplied with ammunition and food.

Today an army and its equipment move by rail and by great fast ships, by armored tanks, and by rubber-tired gasoline-driven trucks, all made of steel. Napoleon had none of these. The amount of steel used per soldier in the present war is probably many hundred times the amount Napoleon needed for his wars.

This change has all occurred in the last hundred years and most of it in the last forty. The tonnage of steel that the United States alone has used to make war material, "ships and planes and tanks," for this war in two and a half years of fighting is probably of the order of a thousand times what Napoleon used in all his wars.

Mr. Manager: I had a pretty good impression of this picture of the rapid growth of the use of steel in war from our own experience at the steel plant. As you say, much of the expansion in use has come in my lifetime. However, much of the steel used in war is lost. When a blockbuster or an artillery shell explodes, not much of it will ever return as scrap. When a freighter or a warship sinks, the metal in it is lost forever. Hundreds of millions of pounds of metal are utterly destroyed. I have wondered whether the resources of these metals in the ores will be enough to keep us going for more than a few decades after the war is over.

Mr. Hotchkiss: That is a very important question. It concerns most vitally every citizen of the United States. It is so important that we must give several sessions of this forum to it. So with your permission let's postpone the answer until later.

Mr. Manager: All right. I can see I was looking farther ahead than is fitting at the moment. But how about the other metals used in war. There are plenty more than bronze and steel. And how about the non-metallic things. There are lots of these.

Mr. Hotchkiss: You are right. We haven't mentioned aluminum and magnesium, the so-called "light metals,"

nor any others. These two are called light metals because they weigh so little compared with steel. If you were to take a cube of aluminum that weighed just a pound and the same sized cube of magnesium, you would find the magnesium cube weighed a trifle less than two-thirds of a pound. A cube of steel of the same size would weigh a bit under three pounds,—2.9 pounds to be more nearly correct.

Both aluminum and magnesium are relatively new metals in war use. The world production of aluminum is reported for 1895 as 1,000 short tons. In one year, 1918, the allies used 90,000 tons for aircraft construction. In World War II the amount used is vastly greater. We shall not know how much until figures are made public after the war. However, figures are available for the end of 1941. The total world capacity for production of aluminum is given as 1,180,000 metric tons. (A metric ton is 2,204 pounds or 1.1 short tons of 2,000 pounds.) In 1937, aluminum output for the world was 481,500 metric tons. In 1937, world magnesium output was 19,800 metric tons. At the end of 1941, world capacity was 103,000 metric tons of magnesium. Virtually all the aluminum and magnesium produced goes into war uses, chiefly for airplanes where their lightness makes them desirable. The increase in their production is due to the tremendous increase in use of airplanes in World War II as compared to World War I.

Mr. Lawyer: You say the world production of aluminum in 1937 was 481,500 tons. I saw a statement in the paper recently that the production capacity in the United States now is two billion pounds per year. That is a million tons a year. Of course it didn't say how much was produced.

Mr. Hotchkiss: The other industrial metals have also stepped up in production due to the war. Table I which I have made up for you gives production for the world and for the United States for 1918, and for the latest war year for which figures are available. Table II gives similar data

for fuels, coal and petroleum. Figures are from *World Minerals and World Peace* by C. K. Leith and others, published in 1943 by the Brookings Institution, from the American Petroleum Institute Quarterly, and from the U. S. Bureau of Mines.

TABLE I

Production of Industrial Metals in World Wars I and II for World and United States in Thousands of Short Tons

| *Year* | *Aluminum* | | *Copper* | | *Lead* | | *Nickel World* | *Tin World* | *Zinc* | | *Silver** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *World* | *U. S.* | *World* | *U. S.* | *World* | *U. S.* | | | *World* | *U. S.* | *World* | *U. S.* |
| 1918 | 148.3 | 62.4 | 1574 | 954.3 | 1288 | 539.9 | 51.9 | 126.3 | 907 | 492.4 | 203.4 | 67.8 |
| 1939 | 735.2 | 163.5 | 2443 | 712.7 | 1919 | 421.0 | 133.4 | 172.7 | 1802 | 491.1 | 265.1 | 65.1 |
| 1940 | 885.1 | 206.3 | .... | 909.1 | .... | 433.1 | ..... | 231.7 | .... | 590.0 | 275.7 | 69.6 |
| 1941 | ..... | 309.1 | .... | 966.1 | .... | 470.5 | ..... | ..... | .... | 652.6 | ..... | 72.3 |

* Millions of fine ounces.

TABLE II

Production of Fuel Minerals in World Wars I and II for World and United States. Coal in Millions of Short Tons. Petroleum in Millions of Barrels

| *Year* | *Coal* | | *Petroleum* | |
|---|---|---|---|---|
| | *World* | *U. S.* | *World* | *U. S.* |
| 1918 | 1469 | 678.2 | 503.5 | 355.9 |
| 1939 | 1680 | 444.6 | 2078.9 | 1265.0 |
| 1940 | .... | 504.7 | 2149.4 | 1353.2 |
| 1941 | .... | 567.7 | ...... | 1404.2 |

The increases of production in preparation for World War II in copper, lead, zinc and silver over the production during World War I are moderate and reflect chiefly the increased scale of mechanization of war activities. These

metals are used in much the same old ways for the same old purposes very largely, but in larger amounts than ever before. The new thing in World War II is aviation. This is reflected in the great increases in aluminum, magnesium and in the greater use of petroleum fuels both for aviation and for surface ships. When the figures for actual participation by the United States are released they will show much greater increases than in the pre-war years for which figures are now available. The increase in world production of nickel is an index of its greater importance in alloy steels, of which much more is used than in the last war. The increase in world tin production represents a scramble on the part of the great consumers to acquire stocks to provide for food containers for their armies before any misfortune of war might cut off the chief producing areas. After Japan captured the East Indies, there is no doubt that the world production of tin fell off greatly although the war prevents the information from being given out.

Another group of metals needed for war purposes are those used for alloying with steel. Their use has been increased more than the increase in steel, because a larger part of our steel production is now of special high quality alloys. In this group the chief alloy metals are manganese, chromium, nickel, molybdenum, tungsten and vanadium. For all these, except molybdenum, the United States is dependent on imported supplies in part or wholly.

Mica, graphite, asbestos, quartz crystals, mercury and antimony are minerals which we import, and must have for our war needs.

The only one of these that is a raw recruit or playing a new role in war work is quartz crystal. Its use is primarily in radio frequency control. Without it the war might have been lost when the blitzkrieg was subjecting England to aerial bombardment. The radar instruments, of which quartz plates are an essential part, enabled the English to

"see" the German bombers before they crossed the Channel. They could prepare their planes and be in the air ready to fight when the German planes arrived. Without radar and its quartz plates the German bombing of England would have been a tragically different story, certainly for them and probably for us.

What would Alexander, or Caesar, or Napoleon or even the generals of World War I have thought if they had been told that little quartz plates would play a crucial part in the greatest war of all time in 1939.

This new recruit warned of the approach of the Japanese planes at Pearl Harbor, but it was such a new thing that it wasn't believed. It has enabled our warships to put the first salvo on the target at night when the enemy ship couldn't be seen. It is so new that its capabilities are probably still far from fully recognized or discovered. But new as is this recruit to the army of natural resources, which we use to help us fight the war, there is no question that it is playing a very important part, and that our navy and army would be seriously handicapped if the supply of quartz plates was cut off.

These little quartz plates are indispensible in radio communication. They enable the commanding officers to know immediately what conditions are on the front lines, and to make their decisions accordingly.

Mr. President: You haven't said much about the importance of oil in war. I am getting along with an A card for my family car so there must be a large part of our production used for war purposes. I think it would be interesting to have more information on the war use of that mineral resource.

Mr. Hotchkiss: Oil production for the U. S. since 1939 has been increased nearly 240 million barrels per year, from 1,265 million to 1,503 million in 1943. Undoubtedly all that increase has gone to war use. Since most of the

rest of us, Mr. President, are also getting along with A cards, it is certain that a large part of our total oil production is used for war purposes. I have seen no official figures for this but it must be at least half of it. Early in '44 it was broadcast by one of the large oil producers that our overseas forces required 1.25 million barrels of gasoline per day, at the rate of 460 million barrels per year. If the uses of shipping and the Navy are to be added to this it must have required well over half of the 1.5 billion barrels we produced in 1943.

Some notion of the relation to the last war is obtainable from the fact that a typical division of World War I had mechanized equipment totalling 4000 horsepower, while a modern mechanized division has equipment totalling 187,000 horsepower—47 times as much. A Flying Fortress making a single trip from our west coast to Honolulu uses up about 4500 gallons of high test gasoline—about 15 tons. And then it has twice as far, or more, to go before it gets to a scene of action. Self-propelled artillery, tanks, trucks, cars, jeeps, and motorcycles all demand their daily rations of gasoline and oil. When you think of the many thousands of units of planes, of gasoline propelled artillery, and of all kinds of land transport the wonder is not that we are asked to give up part of our ordinary civilian uses of gasoline, but rather that we can have any at all. The oil producers and refiners have done a tremendous job of increasing production. Early in 1944 Standard Oil of New Jersey advertised the fact that it and its subsidiaries had produced, since the attack on Pearl Harbor, two times as much oil as the Axis had from every source, and that American oil production was better than ten times that of Germany. But for that we should have much less than we have now.

So necessary is oil for the effectiveness of an army that everything feasible has been done by the Allies to cripple the Axis oil supply. In June '44 we began to read press

reports that the bombing of German synthetic gasoline plants and Rumanian refineries and oil fields were seriously crippling the enemies airforce and land transport.

Napoleon's armies "moved on their bellies." A modern army that can't fly and move on swift gasoline driven wheels is a beaten army.

As we look back over the ages and survey the use of natural resources in war, it is evident that this use has increased step by step with the development of civilization. As men learned more and developed new and more effective instruments they quickly applied them to the art of war. If civilization were defined as progress in the application of science to the common affairs of life, what would we call progress in the application of science to the common affairs of warfare. The two seem opposites. Perhaps what we call civilization is, so far, more directly related to the individual than to nations. Perhaps as nations we are much less civilized than we are as individuals.

Carried to its logical extreme perhaps the use of natural resources in war would effect a return to the principles of barbarous tribal war, in the modern case by barbaric nations, in which the enemy is totally destroyed. A preacher friend recently remarked somewhat wryly that perhaps the old testament tribes had the right idea. He referred me to I Samuel, 15, verses 2 and 3: "Thus saith the Lord of hosts, I remember that which Amalek did to Israel, how he laid wait for him in the way, when he came up from Egypt. Now go and smite Amalek, and utterly destroy all that they have, and spare them not; but slay both man and woman, infant and suckling, ox and sheep, camel and ass."

This was the charge to Saul by Samuel when he anointed him as king. Saul and his army carried out the instructions in part, but they were tempted by the rich spoils, which they kept instead of destroying as they were instructed. They

brought back Agag, the king of the Amalekites, as a prisoner. This disobedience to Jehovah's command enraged Samuel, and verse 33 of the same chapter states that "Samuel hewed Agag in pieces before the Lord in Gilgal."

War is the result of a great complex of conditions and emotions, too involved for even the wisest yet to have solved. But it seems almost, if not quite certainly, to be a law of nature that nations will go to war. We in the United States think of ourselves as people of peaceful intent. Yet every oncoming generation of our youth has had its opportunity to go to war. Just to mention the dates is sufficient: 1781, 1812, 1848, 1865, 1898, 1918, 1941. Why?

I suspect that after each of those wars people heaved a great sigh of relief, as we all did on Armistice Day, 1918, and thought to themselves, "That's over. We'll never have another one." We are even now in 1944 ambitiously and hopefully, and with the firm conviction that characterized the end of each past war, telling each other that *this* time it will be different. I wonder if the human race of 1945 or 1946 will be so superior to all its ancestors that it will know how to make a permanent and everlasting peace.

Perhaps the solution will be for some superbly peaceful people to develop the use of natural resources for war to the logical ultimate so that they can kill off all the "lesser races" in one last war. Then this superbly peaceful people will be the only ones left on earth and can live happily ever after. Does that sound to you like a Hitler dream? It does to me.

But let's summarize these developments of the past in the use of natural resources for war. From a period 5,000 and more years ago until about 600 years ago, warring people used metals for arms chiefly suited to hand to hand combat. For the earlier part of this period, until not long before the Christian era, they were of bronze, and were mainly swords, daggers, spears, and axes. Then iron and

steel became more abundant and the same types of weapons were made of the better metal. Personal armor of steel was developed in the later part of this period.

The development of quality and performance waited on the development of metallurgic practice and better machine equipment. This progress was slow. There was little improvement in quality between the equipment of armies at the time of the discovery of America and the Civil War of 1865. Farragut and Drake would have been quite at home on each others warships. Grant and Wellington and Frederick the Great would have seen comparatively little difference in the small arms and field artillery their armies used.

The great development of the use of steel for war purposes has come since that time. Finer steel, machines to make much better small arms, more quickly and more cheaply, machines to handle and construct heavy artillery of much greater size, accuracy, and destructive effect were not available in Civil War times. Transport of artillery and supplies then was horse-drawn because there was no other mode of field transportation. The one advantage Civil War time had over earlier times was the availability of railroads for primary transportation.

The developments in transport since 1900 have been greatly accelerated by the use of internal combustion engines to drive steel vehicles. This has occasioned a vast increase in the use of steel in war.

Added to these accelerations, up to the end of World War I, is the much greater use of fast moving artillery—motor driven—both as tanks and as lightly armored self-propelled guns.

Another vast increase in the use of natural resources for war is the almost unimaginable numbers of airplanes used in this war, which has demanded the light metals, aluminum and magnesium, in tonnages that we did not think of as within human possibility ten years ago.

## CHAPTER 3

# Development of Peacetime Uses of Natural Resources

MR. PRESIDENT: As we come to the consideration of the development of peacetime uses of natural resources, I am wondering how much we really know of the ways in which ancient man lived and fought, how he raised his food, and made his metals and tools, and how much is inference and imagination as to what we should have done under similar circumstances. I have always had an interest in that, but have never had time to read much about it.

Mr. Hotchkiss: I am inclined to question your statement that you have never had time. Isn't the real fact that you never chanced on an interesting presentation that you could read without being confused by the use of archeological terms that you didn't understand?

Mr. President: Perhaps that is the real truth. At any rate I'd like to know more about it.

Mr. Hotchkiss: Much of what I know about use of resources in ancient times I learned from reading a very interesting book by an eminent mining engineer. He was a classmate of H. G. Wells. When Wells wrote his popular World History, his old classmate was much disappointed that Wells had so little to say about the part mineral resources have played in history. So the classmate, T. A. Rickard, decided to remedy the lack and wrote a book called *Man and Metals*.[1] If you are interested to follow the matter

[1] Published by McGraw-Hill.

farther than the brief statements I have time to give you, I can assure you that Rickard will give you many interesting hours and a more complete understanding of history. If you start to read *Man and Metals*, I'll guarantee you'll find time to finish it.

Mr. Superintendent: One thing has always puzzled me. How can the archeologist dig up an old bronze axe and say it was dated 1439 B.C.?

Mr. Hotchkiss: He can't and doesn't pretend to do it. The time assignment of such a find, even to a given century, is a rare triumph. It is only a hundred years ago that it was first accepted as possible to tell the relative ages of various remains. On the site of famous Troy of the *Iliad* excavators have found successive layers indicating various times of occupancy. The bottom layer, of course, must be the oldest. It contains stone implements. Above it some layers contain copper and still higher ones contain bronze implements. Each period of occupancy must have been ended by some catastrophe, war, pestilence, earthquake, or famine that drove the inhabitants to abandon their homes for some more desirable location. New home builders later reoccupied the site and in turn left their record. By piecing together this kind of information from all the ancient world, by search of earliest writing, and by very skillful interpretation, the archeologists have reconstructed a partial picture back to 5,000 or 6,000 years and more ago.

From this they have described the "ages" of stone, bronze and iron. These have no sharply delimiting dates. It is today the stone age for some wild tribes. When America was discovered it was the iron age in Spain, but the stone age for the Indians. These so-called ages might better be described as dominant cultures. A people that used stone implements might use some bronze at first when it became available through trade or their own discovery and skill. But stone would continue to be used until bronze became

sufficiently abundant to serve their purposes without longer using the clumsy stone implements. Similar gradations, many centuries in duration, between the use of stone and iron and bronze and iron took place until the older and cruder was finally discarded as the newer and better became available so commonly as to make this possible.

When writings and inscriptions on tombs and elsewhere are added to the evidence of excavations, the dating acquires greater accuracy. But even now there are many more questions unsolved than have been answered.

By such methods of study it is known that the first metals men possessed were gold and silver and copper. These are found in nature as metals. They possess beauty of color and are highly resistant to corrosion. The first quality attracted the attention of early man and caused him to prize them. The second preserved them to tell us the uses he made of them.

From the early fashioned forms of gold, silver and copper, it is obvious that men prized them as ornaments. A few who had much used these metals for cups and dishes. The oldest finds are in the form of jewelry, chains, beads, rings, charms, armbands and such. Statuettes, images, and religious symbols were other early uses.

The precious metals were eagerly sought after and kept in royal treasuries, but they were long in coming into use as a medium of exchange. Kings used them as gifts and rewards to their friends and favorites. They were the treasures of peace and the spoils of war.

Mr. Banker: Is there any information as to the quantities of gold and silver men had in ancient times? Did any of the ancient treasures equal those of the present at Fort Knox in Kentucky?

Mr. Hotchkiss: There are many records of the amounts of gold and silver that kings had in their treasure houses, or that they captured in war. To what extent these are

boastfully exaggerated by the owners, or by favor currying court chroniclers, we can't say. Also the difficulty presents itself in comparing their standards of weight to ours. Then finally comes the difficulty of relative values then and now.

Rickard cites the following instances in *Man and Metals*. About 925 B.C. the temples of Egypt received 487,000 pounds of silver and 87,000 pounds of gold in three years. In 517 B.C. the Egyptians paid annual tribute to Darius of 700 talents of gold, or 585,900 ounces. Ptolemy II is stated to have had annual revenue, chiefly from his gold mines, of 14,800 talents, equivalent to $177,600,000. The gold that Hiram, King of Tyre, and Solomon got from their Ophir expedition was 420 talents. This equalled more than 23 tons, and was worth $14,000,000 at $20.67 per ounce—the value before it was changed by the President of the United States in 1934. At $35 per ounce, the present U.S. value, it would be worth more than $24,000,000. In the time of Solomon, its purchasing power was at least that of $140,-000,000 today. The gift of the Queen of Sheba to Solomon was about eight tons of gold, worth at present prices about $7,000,000, but with at least $70,000,000 present purchasing power. During the three centuries they were worked, the mines of Laurium are estimated to have produced silver and lead worth $800,000,000.

To the time of the death of Alexander the Great, the Thracian mines had produced 30,000 talents of gold. Alexander's father received a revenue of 1000 talents of gold per annum from them and piled up the treasure with which his son equipped, fed, and armed the forces with which he conquered the world· He captured at Babylon 40,000 talents of gold and silver.

To answer your question definitely, Mr. Banker, I do not know of any great treasure in the past that equals that at Fort Knox with its more than 22 billion dollars of gold. At $35 per ounce there are in Fort Knox about 640 million

ounces equal approximately to 600,000 talents, or nearly ten times the total of the two large treasures Alexander had. Considering the purchasing power then and now, which was probably around 10 to 1, Alexander possibly had as much purchasing power in gold as lies in Fort Knox. At least it can be said with a fair degree of probability that his wealth was of the same order of magnitude as that at Fort Knox. It was the equivalent of many billions of dollars.

A commentary on the relative values of precious metals is quoted by Rickard from Agatharchides of Cnidus who wrote in 170 B.C. about an Arabian region where there was abundant placer gold. "The smallest pieces are not less than olive stones, the medium-sized equal a medlar, and the biggest a wall nut. They wear these nuggets around their wrists and necks, threaded alternately with transparent stones, and sell them cheaply to their neighbors; copper is worth thrice, iron double, and silver ten times its weight in gold."[2]

Before the Christian era there was much gold and silver found in the regions tributary to the eastern Mediterranean, the center of the civilized world of those ancient times. From being the precious treasure of the king and his court they gradually came to be used as a measure of value in trade. The earliest uses in trade were as coils of wire or small bars that must be weighed at each transaction. Later on the happy invention was made of making pieces of standard weight—so they could pass from hand to hand without the bother of weighing. When these standard weights were stamped by recognized authority they became coins as we know them. The earliest Greek coins were of silver and were struck about 700 B.C. After the invention was first made its use gradually increased. Much of the world's trade still continued to be carried on by barter for many centuries, some of it is even today, but the use of

[2] T. A. Rickard, *Man and Metals.* McGraw-Hill, p. 256.

coins grew and expanded. Less valuable coins were made of copper and bronze, and more valuable denominations of gold.

With her silver coins made of the metal from her slave-operated mines at Laurium, Athens was able to dominate the trade of the Aegean Sea and Asia Minor. The coinage was a lubricant that facilitated trade and enabled it to expand. The possessor of abundant gold and silver for coinage was sure to be the dominant commercial and political power. These precious metals that we think of as not being useful in the ordinary sense—the woodsman couldn't use them to make his axe, nor the farmer to make his plow or his hoe—have a use of a different kind that is just as truly valuable and just as truly serviceable to mankind as the "useful" metals, copper, bronze and iron. That use as a medium of exchange has grown vastly in importance, as man has become more civilized The shortage of metal coins has occasioned distress and low prices back as far as experience goes. Its abundance has made prices high when goods are valued more highly than the amount of currency they used to be worth. When a newly discovered gold field brought a great increase in the available gold in Italy, in the first century A.D., the value of all the gold decreased one-third in the space of two months.

When the Roman conquests brought in the vast treasures of the captured countries the same effect was produced. A house sold for 75,000 drachmas, and only a few years later resold for 500,000 drachmas in the early days of the Roman Empire.

Economists have studied these things ever since Roman times and have drawn up theories of money that are far from agreement with each other. They are doing so today. When the doctors disagree, who am I to prescribe. I only know that the precious metals from prehistoric time have been of tremendous importance in the development of man

from his original savage state to the present. They are vital natural resources which we do not yet fully understand how to use.

But to return to the other metals. In addition to the gold, silver and copper for ornaments and treasure, it was early found that beating copper into useful shapes hardened it greatly so that it was useful for knives and axes and other sharp tools. At first the only metals were those found in nature. In those times copper was a precious metal. Only after men learned to smelt copper from its ore did it become sufficiently abundant to graduate into the "useful" or tool class and begin to replace stone tools.

*Man and Metals* puts this first introductory step of the age of metals as probably being between 4000 and 3500 B.C., but it was a long time before metal became a thing of use to the common man. By the rich in Egypt, copper was used for hinges, nails, and other forms useful in building.

Bronze was first used about 2200 B.C. in small quantities. It did not become common in the eastern Mediterranean area until about 1500 B.C.

Bronze is harder than copper and so makes better tools. It, too, with the proper tin content is hardened by hammering. It also has a distinct advantage over copper in that it can be easily cast into desired forms. The first bronze was probably made accidentally, from copper ores that contained tin. There were many deposits of such ores tributary to the eastern Mediterranean. Early bronze varies widely in tin content. It was produced before tin was known. Only when tin was discovered to be a distinct metal could alloys be made of approximately constant qualities. It is probable that tin, as a metal separate from bronze, was known about 2000 B.C. However, bronze was not available in any considerable quantities until about 1200 to 1500 B.C. and it is assumed that an increase in the tin supply at that time was the reason. Then bronze tools for the farmer and the

artisan were widely used. Simple tools and fittings were made of bronze, chisels, adzes, knives and axes. Swords and daggers and other implements of war required the same kind of bronze as the peacetime tools. Casting bronze was a much less laborious operation than hammering a lump of copper into the shape desired. The molds were first cut in stone which left one side of the tool unmolded. Later two stones were cut to make the two halves of a mold. This was further improved by the invention of the closed mold. The dentist of today casts a gold inlay by making a wax model which he imbeds in a matrix of plaster of paris. When the plaster has hardened he heats it and melts the wax out leaving a perfect mold. The ancient bronze worker did a similar thing. He made a wax model of the form he wanted to cast, encased it in clay which he dried and then heated to melt out the wax. Thus he had a perfect mold into which he could pour his molten bronze.

The finest bronze work was done on statuary and vases and other art objects. In the bronze age there was never enough metal to make all the tools the farmer and the artisan could use, but the few who owned the wealth could provide themselves with beautiful art work and their temples with bronze ornaments and utensils for worship. The makeup of society was lords and slaves, with few in between. It was the business of slaves to produce and of lords to enjoy. It was to take more than three thousand years and the development of the use of two then unknown natural resources, first iron and then coal, to a high degree before slavery as a general basis of social structure would pass out of the picture and give way to an economy of free men. An ancient Greek philosopher once wrote that "human slavery will continue until the loom weaves of itself." So long as slaves did the work it mattered little whether they used efficient tools. There was little occasion for accomplishment until there was a reward that served as

an effective stimulus. Slave economy did not offer this effective stimulus and so progress was slow in the development of the use of natural resources.

The earliest iron found by the archeologists leads some of them to conclude that it was known in China about 4000 B.C. and in Egypt about 3000 B.C. But these dates are very much to be doubted. These early irons are like the other metals known at that time, finds of the metal in nature, not smelted from the ores. The only common native iron is that which falls as meteorites. The early Egyptian name for iron is "metal from heaven." Iron then was a precious metal and used for ornament. Quoting Rickard, "Petrie asserts that no iron was 'intelligently produced by an understood process as a regular manufacture' before 1200 B.C." (And) "has stated to the author that there is no satisfactory evidence of the industrial use of iron in Egypt before 800 B.C." . . . "For the present we may accept the finds made recently at Gerar, in Palestine, as the earliest fabricated iron of certainly known date . . . and that by 1200 B.C. the people of Gerar were making heavy tools, including hoes and plough-points."[3]

In the storehouse of King Sargon II of Assyria who was killed in 705 B.C. was found 176 tons of iron bars, with chains and horsebits and other finished iron things. In I Samuel, XIII, 19–21, it is stated that for the lack of smiths "all the Israelites went down to the Philistines, to sharpen every man his share, and his coulter, and his axe, and his mattock. Yet they had a file for the mattocks, and for the coulters, and for the forks, and for the axes, and to sharpen the goads." These were all undoubtedly iron implements and show the use of iron in those ancient times.

In the Old Testament, written from 800 B.C. on, there are numerous other references to tools of iron, axes, mattocks, harrows, saws, yokes for the necks of captives, and at least

[3] T. A. Rickard, *Man and Metals.* McGraw-Hill, pp. 143 and 836.

one reference to an iron furnace. All indicate that iron had become the chief metal tool of the farmer and the artisan between 800 and 600 B.C.

Rickard states that "in Neo-Babylonian days (625–550 B.C.) copper was used for the tires of cart wheels, which suggests that iron must have been scarce, or difficult to fabricate."[4]

The early iron was all what today we call wrought iron. The ore was reduced in a small furnace with charcoal, to a spongy mass of white hot iron and slag. The slag was partly eliminated by hammering. The process of hardening by quenching implies the use of steel, but steel was unknown until shortly before the Christian era. Wrought iron, heated in the forge, will absorb some carbon, and so can be hardened by quenching. This was known in 1200 B.C., before the days when iron became commonly used.

The earliest steel was made in India by heating iron bars with wood in sealed pots. This was traded in and reached Rome. It was this steel of which the famous Damascus swords were made.

These primitive processes supplied the iron and steel needed by the relatively static economy of ancient and medieval times from 1200 B.C. to about 1500 A.D. Iron and steel were used in much the same fashion throughout this period of nearly 3000 years. They supplied tools and implements for the farmer and the artisan and were used for chains, equipment for domestic animals, nails, hinges, keys, rods, and other building needs. They also supplied the soldier with his weapons and armor. With the passage of the years the supply of iron increased, and the methods and skill of smiths improved, so that both quantity and quality were bettered. The needs of men for iron and steel throughout this long period were supplied by much the same processes as in the early days, the small furnace fired with

[4] T. A. Rickard, *Man and Metals.* McGraw-Hill, p. 851.

charcoal, in which the iron ore was deoxidized, but the resultant iron was not melted. The product of these furnaces therefore could not be cast in a mold as bronze was.

The temperature required for melting the iron is much higher than that required merely to deoxidize it and reduce it to the metallic state. The heat required to melt the iron required a stronger blast than was available before the devising of power driven blowing devices.

About the beginning of the Christian era the Romans conquered the rest of the civilized world and acquired their hoards of wealth of gold, silver, copper and bronze. They acquired the mines of Spain and Greece, and all others of the known world. The lavish spending of this treasure caused a great increase in the need for the useful metals. They needed iron to bond their multitude of great masonry structures. They bonded the stone with iron bars about which they poured melted lead. Lead pipes were used to convey water. These were made of strips of sheet lead bent around a rod and the edges soldered together. Lead sheets were used for lining their baths and for making coffins. Sheets were also used for roofing.

The riotous squandering of the looted treasures of the world and the avid exploitation of captured mines by the Romans dissipated this wealth in a short time, caused the exhaustion of the mines and contributed to the ultimate downfall of the empire. An estimate of the gold and silver in circulation in the empire in the reign of Augustus is quoted by Rickard as being $1,290,000,000, which by 115 A.D. was reduced to $165,900,000,—nearly seven-eighths had gone. This spending produced a great drain on the useful metal resources as well as on gold and silver. Iron and lead, tin and copper were in great demand and the work of production was pushed hard. It skimmed the cream of those known deposits which they knew how to utilize. Despite this the amount of metal used by the Romans was small compared to

that we use in our industrial age. We have uses for the metals of which the Romans did not dream.

The Dark Ages—roughly from 500 A.D. to 1500 A.D.—was a period of relatively little use of the metals. In the latter half the use of iron increased, but it was not until about 1340 that the blast furnace came into use, and iron could be melted and cast. The strong blast to generate the necessary heat in the furnace was produced by bellows run by water power. The honor of this invention is claimed by Belgium. Such metal was of poor quality at first, and there was little use for heavy units of iron except for cannon.

All early cannon had been cast of bronze or, with much labor, made of wrought iron. The iron cannon were very poor as might be imagined and the bronze cannon were very expensive, so there was every incentive to make better cast iron that could be used for these heavy units.

"Henry VIII," quoting Rickard, "supplemented his inadequate supply of bronze artillery by using cannon of wrought iron; they alternated on his own ship, the *Grace de Dieu*. The cost of bronze in those days was £74 per ton, a price that must have taxed even Henry's resources; therefore it is not surprising to find him in 1543 arranging with a Sussex founder to supply cast-iron cannon at £10 per ton. In the sixteenth century Sussex became the center of cannon founding, for that was the chief purpose to which the iron industry was devoted." . . .

"Secondarily, cast iron was used for a preeminently peaceful purpose, namely the backs for domestic hearths."[5]

This early development of cast iron was preparing the way for later vastly greater uses. When the need came it was ready in abundance.

In this second half of the Dark Ages the art of mining was revived in Cornwall and in Saxony. The discovery of silver at Freiberg in 1170 was followed by similar discoveries over a

[5] T. A. Rickard, *Man and Metals*. McGraw-Hill, pp. 888, 889.

period of several centuries. This metal gave to the Germans the commercial ascendency over Europe just as that of Laurium had served Athens nearly 2000 years earlier. This marks the time of the beginning of the great German bankers who were the most important financiers up to and including the early part of the "industrial revolution."

German miners were free men, not slaves as in Roman days. They acquired recognition as members of an honorable occupation, and won dignity and privileges. They organized strong guilds, which were the predecessors of modern labor unions. The mines they discovered were their property. The free man reaped the advantages produced by his discovery, or by his superior energy and skill. So he had incentives that led to rapid development of the art of mining and treating ores. If the easily worked ores near surface played out and left only the more complex deeper ores, the miner was not long in finding ways to solve the problems, and make use of the new kinds of ores. When the mines reached depths that made primitive methods inadequate, he devised ways to overcome the difficulties.

The Cornish mining industry began to revive after the Norman conquest. Tin found an increasing market for the manufacture of pewter utensils, the making of which was dominated by the guild of pewterers in London. Eventually they secured a monopoly of the pewter business about 1500 A.D. The high prices they charged, as always in such cases, stimulated competition. The finding of tin in Saxony made this competition effective by furnishing an adequate source of metal to make the popular tin-lead alloy that looked so pleasingly like silver. As so often happens the greed of a monopoly created its own remedy. The charging of unduly high prices in any kind of business offers a rich prize to those who want to compete. The disease will oftentimes cure itself if patience and good nursing are afforded the sufferer. The London pewterers were forced to meet the competition of

France and Flanders, and for centuries did so successfully until the Dutch brought in tin from the East Indies in the early decades of the 19th century.

The size of the tin business is indicated by the fact that in 1801 the production of English tin was 2,500 tons, and the Saxon and Bohemian tin production was probably much less. Since pewter is three parts tin to one part lead, the total tonnage of pewter vessels, even if all the tin had been made into pewter, must have been what we would consider a very small business today.

The total production of tin from Cornwall has been estimated at 2.5 million tons from 500 B.C. to 1800 A.D. Malaya is said to have produced one million tons of tin from 1400 A.D. to 1800 A.D. and probably several times that amount before 1400 A.D. Since 1800 A.D. the world is estimated to have produced over 6.5 million tons of tin to 1930. Half this total has been produced since 1905.

The greater use of tin since 1800 had to wait on the greater needs developed by the industrial revolution. Evidently we have uses for tin which were undreamed of by the tin miners of 1800.

At the close of the Dark Ages the discovery of America brought to Europe the gold and silver of that new continent. The total amount of gold and silver in Europe was increased from $175,000,000 to $650,000,000 in about one century after Columbus' voyage. This was a vitally important factor in the development of all kinds of business as well as in the demand for other metals. Wheat sold for 10 shillings per quarter (8 bushels) in 1495, and for 28 shillings in 1602, according to Rickard. He goes on to say, "The fresh supplies of gold and silver helped to break the feudal fetters of Europe, to shatter the medieval guilds and monopolies that had cramped industrial progress, and to give new hope and opportunity to workers, particularly the middle class—the professional man, the skilled artisan, the yeoman

farmer, and the town tradesman; and it was their rise to political influence that was the critical result of the flood of precious metal tapped by the conquistadores. The ultimate consequences, therefore, of the adventurous exploits of Cortes, Pizzaro, and their followers was to benefit the civilized world by spreading material well-being among those upon whom the industrial and political progress of the world most depends. By so doing it stimulated intellectual progress also, creating the leisure in which the scientific discoveries and mechanical inventions of a later day were made and applied to the benefit of humanity."[6]

Mr. Manager: I have been very much interested in the picture you have given us of the use of the various metals. I note that you have limited the picture to about 1800, with occasional glimpses after that time. I suppose you are leaving the period of the industrial revolution for the next picture. But you have said nothing about coal, a natural resource that today exceeds all others but oil in total money value. Didn't that come into use in important degree in the centuries long preceding 1800?

Mr. Hotchkiss: You are right. The industrial revolution changes the picture so completely after 1800 that it does need to be considered separately. Men knew much about the manufacture and use of metals from their ores before 1800; but they learned much more after that date, so that they were able to meet the new uses which caused demand to increase many, many fold.

They knew the simpler uses of gold, silver, iron, copper, tin, lead, zinc, quicksilver and sulphur. Nickel had been produced in the chemical laboratory, but was not an article of use. Of the non-metallic resources people used stone and slate for building and roofing, they used whetstones and other abrasives, and soapstone, millstones, salt, niter, and some other salts. The science of chemistry was in a very primi-

[6] T. A. Rickard, *Man and Metals*. McGraw-Hill, pp. 707–709.

tive state, and most of the chemical elements were yet to be discovered including many of the minor metals and some not so minor, that we use today. Furthermore, uses for the known metals and non-metals were to be developed that were not imagined at that time. Portland cement was a quarter century in the future; aluminum was nearly a century away. Magnesium was more than a century away. Manganese and the other steel alloying metals were from a half century to over a century in the future. The commercial development of that scientific curiosity of 1800, electricity, was not to begin for three-quarters of a century and demand unheard of quantities of copper. Petroleum was to wait nearly three-quarters of a century for its extensive use to develop. The commercial preserving of food in tin cans was more than three-quarters of a century in the future as a use for tinned sheets of steel. This use of tin was to far overshadow all the uses known in 1800. In its article on inventions, the *Encyclopaedia Brittanica* lists the preserving of food in tin cans as probably the greatest modern invention. Without it, it would be impossible to feed our armies in all quarters of the globe, so while tin is not of use as an actual fighting instrument, it ranks as one of the leading aids in the present war.

But as to coal, your question is a very important one Mr. Manager. Its existence was known to the ancient Greeks, who called it *lithanthrax*—stone-coal—and whose smiths used it for their fires at times. Marco Polo mentions its use by the Chinese in 1275 A.D. Ancient literature contains many references to coal and its use, but usually they have a sense that implies the unusual and therefore noteworthy.

Rickard gives 1243 as the date of the earliest mention of the actual working of a coal seam in England. The forests of England had been used to an alarming extent, in many parts of the country, to provide charcoal for the smelting of tin, iron, lead, and copper, and for domestic use. Coal

first came into use in England as a less desirable fuel for domestic purposes. The first coal used was undoubtedly the weathered parts of the veins that cropped out at the surface, and so not of very good quality. Parliament urged the king in 1306 to prohibit the burning of coal in London, which he did in 1307. But coal was the fuel of the poor people who could not afford charcoal, and so London was not long without the "stench" of coal smoke.

There continued to be dislike of coal and prejudice against its use for domestic fires, not only in London, but almost everywhere it was used until into the 19th century. But its use expanded until there was a thriving industry which supplied home use and much for export to France. The prosperity of the trade is indicated by the fact that it was the subject of special taxes in 1379. By 1635 the coal taxes were one of the largest sources of the King's revenue.

One interesting by-effect of the burning of coal was that it led to the building of chimneys. Charcoal burned without smoke or unpleasant fume and could be used in any room. People knew nothing of the danger from carbon monoxide in those days and so didn't worry about this odorless gas. Not so with coal,—it required a satisfactory outlet for its combustion products. In 1419, a London ordinance forbade chimney construction of wood and required that they be stone or brick. Chimneys also came to be a subject of tax.

The use of coal for melting glass in 1635 was one of the earliest industrial applications. Patents were granted in England in 1612, and in 1619, for making iron with coal made into coke, instead of charcoal. But it was not until 1745 that commercial success was attained. Coke was so much more effective than charcoal that the charcoal iron producers did all they could to prevent the success of the coke furnaces of the 1619 inventors,—even to slashing their bellows and organizing riots among their laborers.

Let me read you a paragraph from Rickard: "In 1740 the domestic (English) production of iron had dwindled to 17,350 tons, all made with charcoal. At that date the total output of Europe did not exceed 100,000 tons, of which 60,000 were made in the forest-lands of Sweden, Norway, and Russia; and half of their product came to England. The consumption of iron in continental Europe did not exceed two pounds per capita, whereas in England it was 15 pounds per capita, which fact indicates the industrial energy of the English people. Nevertheless, their own output of iron declined to a tenth of its former tonnage, and the high cost of imported metal became a burden upon domestic industry. It was the lack of fuel that crippled iron smelting, the scarcity of wood for making charcoal being due to the larger profit to be derived from using the land for pasture. The introduction of a new fuel into iron making had become an urgent necessity."[7]

The development of coke as a fuel for the blast furnace saved the iron industry in England. It made possible a great expansion for which charcoal would have been wholly inadequate. It might be said that in this application to iron smelting, coal took on its first big job among the many that were to be given it when men found what a willing efficient slave it was. Men began early in the 18th century tentative efforts to hitch coal to its next big job, the application of its power to industrial use.

The deepening of the mines, both tin and coal, was stopped when they reached water. The Romans had used crude man-operated wheels and Archimedes screws to lift water out of their Spanish mines. They had also driven long drainage tunnels under ore bodies to draw off the water. Deeper than such devices permitted they could not go. The pumping out of this water so that deeper ore could be mined was the first need men had for large amounts of mechanical power.

[7] T. A. Rickard, *Man and Metals.* McGraw-Hill, pp. 896–897.

In 1699, Thomas Savery described his "fire engine" in which the water was allowed to flow into a cylinder and the steam turned on to force it out. This was exceedingly wasteful of steam, and could force water no higher than the direct steam pressure permitted. While he used pressures up to 100 and even 150 pounds, incidentally he made his steam in boilers without a safety valve, this sufficed to lift water only 200 to 300 feet.

Savery's pumping engine was followed by that of Thomas Newcomen, who introduced a piston operating a walking beam on the other end of which were pump rods. This was so much more efficient than Savery's engine that it rapidly came into use. It held its place for three-quarters of a century as a machine for pumping mines. Both Savery's and Newcomen's pumping engines condensed the steam in the cylinder with sprays of cold water.

Watt, in 1763, increased efficiency greatly by letting the steam escape into a condensing chamber separate from the cylinder. Still the only use was for pumping mines. His engines began to be used in place of Newcomen's. In 1781 and 1782, Watt patented the double acting engine, admitting steam to both sides of the piston, and adapted the steam piston to the production of continuous rotary motion of a shaft and fly-wheel.

The steam engine was now developed ready to furnish power for any kind of industry. Coal had been harnessed to the smelting of iron and other metals as its first great job. Now it was harnessed to develop mechanical power for the use of mankind for the making of any product to which he wanted to apply it. For the first time in history man had the means to make all the iron he wanted and the power to pump his mines and run all the industries his inventiveness could devise. The world was ready for the industrial revolution with tamed forces of nature at its command that were to multiply the productiveness of man's efforts a hundred fold.

The time was at hand for the fulfillment of the prophesy of the ancient Greek philosopher, who said, "human slavery will endure until the loom weaves of itself." Not for much longer could man afford to keep slaves when at his hands was the unlimited power of coal and steam. We like to think that slavery was abolished in the last century solely because we had attained a higher and finer sense of moral responsibility in the matter.

I believe it is possible that the general human attitude toward slavery is indicated by the action of the Germans in this war in enslaving millions of men and women from the territories they overran. Whatever of high moral attitude against human slavery was possessed by one of the most highly civilized nations of the world evaporated instantaneously under the economic pressure of war needs. There are, no doubt, many Germans of high moral fiber who regret this, and who would not have countenanced it if it had been theirs to decide. But the nation as a whole has countenanced it and has expressed no regret. We have had no such need as faced the Germans. How we would behave if we were faced by such a compelling need, we can't be too sure. A pessimist might, with much assurance, add to the prophecy of the Greek philosopher the words, "and when the loom shall cease to weave of itself human slavery will return," with all that that implies.

Mr. Lawyer: What are you trying to do, start an argument? I had accepted without question that human slavery was a thing of the past. We settled that in the Civil War. You shock me when you suggest that our attitude toward slavery may rest on an economic basis rather than on high moral grounds. Yet I remember that there is a good old principle of economics that men will supply their needs with the least effort necessary to themselves. Men in the past did that partly, at least, by using slaves. I have been wondering, as you have shown the developments

of the past, what they might signify as to the future. Men weren't notably different in their motives, their good and bad characteristics, in the days of the Roman Empire, from what they are today. I suppose if we people of 1944 were to live in the same conditions that the Romans did 1900 years ago, we would do much as they did. If I admit that, I'll have to concede that if conditions, at some indefinite time in the future, become such that we no longer have our cheap mechanical slaves—if, in other words our economic conditions were to become equivalent to those of the Greeks and Romans,—perhaps then we would do as they did with regard to human slavery.

Mr. Hotchkiss: Perhaps I spoke too bluntly, with the purpose of emphasizing the point. I can assure you that I don't think we will return to the institution of human slavery in any short period of time. There is no fear that our present cheap mechanical slaves will run away from us for many generations. We even have the prospect, from scientific developments, that we may add to and materially increase our mechanical slaves—in other words, our command over the resources and forces of nature and our use of them. But—and I would make it a big, underlined "but"—men somehow love power over their fellows. Such love of power is not limited to Hitler and his kind. In some degree, often powerfully, it actuates many men in all our governments, local, state, and national. It actuates many men in business, in the church, in labor unions, and in our educational system. Unless we are ever watchful, men with such motives will gradually, or even in revolutionary fashion, increase their power over us as far as we will let them go.

Mr. Lawyer: In other words you are emphasizing the importance of "eternal vigilance as the price of liberty." I like the fuller statement of this principle so much that I carry it in my notebook. It is from a speech by John P.

Curran, a lawyer of renown in Ireland, who was born in 1750. Let me read it to you. "It is the common fate of the indolent to see their rights become a prey to the active. The condition upon which God hath given liberty to man is eternal vigilance; which condition if he break, servitude is at once the consequence of his crime and the punishment of his guilt."

Mr. Hotchkiss: We have wandered a bit from discussing the use of natural resources into comments on consequences. Before we return to our knitting, I have a quotation I carry in my notebook that is along the same line which I should like to read to you. It is from John Stuart Mill, who died in 1873. "A people may prefer a free government; but if from indolence, or carelessness, or cowardice, or want of public spirit, they are unequal to the exertion of preserving it; if they will not fight for it when directly attacked; if they can be deluded by the artifices used to cheat them out of it; if by momentary discouragement, or temporary panic, or a fit of enthusiasm for an individual, they can be induced to lay their liberties at the feet of even a great man, or trust him with powers which enable him to subvert their institutions—in all these cases they are more or less unfit for liberty."

Mr. President: I am glad you two have taken this side path for a few minutes. The subject of our liberties is one which many people are beginning to discuss. We have built a great economic machine, because we have "enslaved" the resources and forces of nature. It is going to take all the intelligence and all the "eternal vigilance" we can muster to see that in the operation of that machine we don't lose the very things that made it possible in the first place. Bob and Dick, I hope you will do some serious thinking about it. Yours is the generation that must see that all these good things are not lost to the forces that are ever vigilant to gain power.

Mr. Hotchkiss: Well, let's devote a little time now to the developments in the use of natural resources that followed the beginning of the 19th century—the cycle that we have been referring to as the industrial revolution, which, perhaps, might more properly be referred to as the industrial evolution. We have seen the iron industry released from the shackles of an inadequate fuel supply by the development of the use of coke. We have seen the development of the steam engine in which the mechanical power of coal is ready to be applied to the needs of men.

The first great step was the application of steam power to transportation. In 1814 George Stephenson made the first really effective steam locomotive. It was primitive and it ran on wooden rails, but it hauled 30 tons up a gentle grade at four miles per hour. This was a utilization of natural resources so effective that it expanded rapidly. I have made a table to show you the mileage of steam railway in England and the United States for a few different years to show how it increased after 1825.

TABLE III

Railroad Mileage

| *Year* | *England* | *Year* | *United States* |
|---|---|---|---|
| 1825 | 26 miles | 1840 | 2,709 miles |
| 1844 | 2,236 " | 1850 | 8,683 " |
| 1850 | 6,635 " | 1860 | 30,283 " |
| 1870 | 15,310 " | 1870 | 53,878 " |
| 1890 | 20,075 " | 1880 | 94,671 " |
| | | 1890 | 163,597 " |
| | | 1900 | 193,346 " |
| | | 1910 | 240,439 " |
| | | 1920 | 252,845 " |

In 1890, the railway mileage in England had reached about its present total. In the United States it increased to a maximum of 254,251 miles in 1916 and then decreased to 249,131 in 1930. This expansion was accompanied by very

great improvements in the efficiency of use of coal and iron. Steel was not available in the early days, either in price or quantity necessary for track, so rails were made of the less satisfactory wrought iron. Some early unhappy experiments with cast iron proved its unsuitability. Steel was not available, cheaply and in quantity, until after the Bessemer process was invented in 1856, and had gone through the necessary development up to the quantity production stage.

Locomotives developed from the tiny inefficient type of the early days to the monsters of the present, propelled by steam, oil or electricity.

Cars changed from the almost toy sizes at first used to the modern hundred ton freight car and the luxurious air-conditioned pullman of today.

All these things and numberless other improvements contributed to the increased service that the two natural resources of coal and iron were able to render to transportation. This service is best measured in units per person of our population from data given by the Association of American Railways. In single years before the present war, the railroads of the United States have given passenger mile service equivalent to carrying every man, woman, and child in the country 445 miles in one year. In ton-miles of freight, they have carried the equivalent of one ton for each of us 3,887 miles. In the present war years, this has been nearly doubled. In 1943, our transportation system performed the equivalent of carrying one ton for each of us over 7,400 miles. Of this, the railroads carried that ton for each of us 5,400 miles. The Great Lakes carried it 814 miles, the pipelines carried a ton of freight for each of us 740 miles. Intercity trucks transported that ton 333 miles, and our inland waterways 185 miles. All this was done by coal and steel, and later, oil, harnessed for our transportation.

What this means to us is beyond our imagination. If we try to think of what we would do without this tremendous bulk of transportation, we find we have little basis of experience with which to make comparisons. Before the days of railroads it oftentimes cost more to haul a bushel of wheat forty miles—even with the pitifully low wages of those days—than the wheat could be sold for at the end of the journey. Without our railroads most of our farmland would not be worth the dollar and a quarter an acre for which the government sold it to the early settlers. Our great forests, our great deposits of coal, iron, copper, oil and other natural resources would be almost as useless to us as they were to the Indians when America was discovered. It would be impossible to feed our great cities or to provide them with water, heat, and light—there would be no great cities such as we have today, and the few relatively large cities would be on water where sailing ships could bring food to them as they did in the days of the Roman Empire.

Parallel to the rapid development of railroads in the 19th century was the application of steam power to ships. This was first applied to wooden ships because they were the only ships there were. There was bitter prejudice against all such revolutionary innovations as railroads and steamships. Ridicule was heaped on those who first introduced them. The British Admiralty resisted the application of steam to ship propulsion. Many insisted, because iron would not float on water, that iron ships would sink. That seems absurd to us, but we must remember that even well informed people in those days knew relatively little about physical principles that six-year-olds of today take for granted. Present day six-year-olds do not expect their hollow iron toy boats to sink, unless they fill them with water.

The first steamship to take a sea voyage was the *Phoenix* which "sailed" from Hoboken to Philadelphia in 1809. Regular trans-Atlantic steamship service was inaugurated

in 1838, by the paddlewheel steamer *Sirius*, a 700 ton boat, 200 feet long with 320 horsepower engines. A second steamship, the *Great Western* of 1340 tons, sailed from England four days after the *Sirius* and arrived in New York only a few hours after the *Sirius*.

This was in 1838, only 106 years ago, in wooden ships of 700 and 1340 tons. Iron ships were used much earlier, but had gained little acceptance. In the United States we built 90 steamships in 1838, 63 in 1840, 159 in 1850, 264 in 1860, and 348 in 1880. In that last year the American Merchant Marine consisted of 2,856,476 tons of sailing ships and 1,211,559 tons of steamships, part of them still built of wood. In the United States in 1868 we built 2801 tons of iron ships. In 1870 the tonnage built was 7,602, and in 1874 it increased to 33,097.

So you can see the acceptance of steam and iron in ships was a much more gradual affair than the acceptance of the steam railroad for land transportation.

The great consumption of coal to generate steam for the engines of the railroads and steamships made it most profitable to consider ways of increasing efficiency. The development of science and engineering because of the need for them, and the accompanying development of efficiency of the steam engine is a history full of thrilling stories. It is enough here to give the net results. It is doubtful if the early forms of steam engine were able to translate more than a moderate fraction of one per cent of the heat energy of coal into mechanical work accomplished. It might be stated in another way—for a hundred pounds of coal burned to make steam only a small part of one pound was actually effective in lifting water out of the mine.

Modern improvements have increased the efficiency of the use of coal and iron in steam power production so that we now get from 4% to 10% in ordinary practice, and up to a maximum of about 35% effective use of the heat energy

in the coal. The 35% efficiency is possible only in large stationary generating stations using powdered coal fuel, the most efficient boilers yet devised, steam temperatures and pressures that are limited only by the ability of metals to withstand them, and steam turbines to transform the energy in the steam into rotary motion of the electric generators.

Another aspect of this increase in efficiency is also a most interesting story. If the user of a mine pump in 1750 had had on hand coal to last him for a month, and some magic wand had touched his machinery and given it maximum 1944 efficiency he would have found his coal pile would last him four to eight years, instead of the month. His coal would do fifty to a hundred times as much work as he expected to get out of it. That magic wand has been applied. It is modern science and engineering. Use of that wand has enabled us to get up to 35% of the energy in the coal. But we are losing 65% in the most efficient plants. Suppose some other wand, not yet known to us, could have touched the 1750 mine pump and made it, what we someday hope to attain, 90% efficient. The pump owner would have found the coal he bought to last him a month would now be enough to last him about fifteen or twenty years, an improvement of 200 times. That still awaits the doing, however. But it's a goal worth while for your generation to shoot at, Dick and Bob. When it is accomplished it will pay many people a handsome profit and will be of great benefit to all mankind.

In England in the middle 1800's, apprehension arose as to the duration of her coal supplies. Production was increasing rapidly and it was evident that the coal supply could not last forever. This fact began to impress itself on the informed public, and ever since then English leaders, both in government and industry, have been aware of the importance of making the coal last as long as possible. Informed

people in the United States know that mineral resources cannot last forever, that every ton of iron ore and coal, and other minerals as well, taken out of the ground leaves just that much less for the future. But even in these strenuous war days, the average citizen does not know that our war capacity is dependent on natural resources we do not have in this country. He thinks we have ample supplies of all the metals and ores we need.

The best way to multiply our exhaustible supplies of natural resources is to use them more efficiently. We have found that it is possible, in effect, to multiply the world's coal supply by at least 50 times by recovering 50 times more power from each pound. We have the attractive problem before us of trying to improve methods and machines so we can use coal with at least 90% efficiency.

We are doing a similar thing with iron. By making special steel alloys to fit each particular large purpose, we are making one pound of iron serve the needs that used to take several pounds. By using steel and concrete in construction, we are saving large tonnages over the early days when cast iron columns were used.

But there are many other services we have taught our natural resource slaves to perform for us. Coal and iron are the slaves we depend on for the drudgery and the heavy work. We have developed a most useful slave to aid in both these jobs. I refer to electric power, which we must consider to be a natural resource, one of the many very interesting developments of the past two hundred years.

Electricity was an interesting toy in the laboratory up to the middle of the 19th century, with a lot of promise that when it reached maturity it would be a worthwhile slave. While it was still only a subject of scientific curiosity Faraday is reputed to have been scornfully asked by a member of Parliament of what use his experiments were. Faraday testily replied, "Perhaps you can tax it some day." If he had told the legislator that electricity was a great

natural force which was growing up and would be one of the most useful slaves for mankind in less than a hundred years from that time, he would have been even more broadly truthful.

About 1850, when it was found that electricity could be generated by mechanical power, it was ready to go to work. The dynamo was hitched to the steam engine and was ready to add copper to coal and iron in the list of most useful mineral resources. Copper was next best to silver as a conductor of electricity, and because it was abundant and relatively cheap, and silver was not, copper added this tremendous new job to its functions.

As with most metals and forces newly discovered, it took some time to find jobs electricity was best able to do. The first important use was in arc lighting. Then in the '70's it was found by accident that if a direct current dynamo was connected to the current from another that the first would serve as a motor. Thus a vast new job was found for electricity. This power job developed into the tremendous field of power application in which almost every manufacturing plant today uses dozens to thousands of motors; and street cars and hundreds of miles of main line railroad are operated electrically. Lighting developed quickly from the inefficient objectionable arc lamp to the incandescent lamp and now to neon and fluorescent lamps.

When electric power entered the field of household appliances only about a quarter century ago, it brought new comforts and conveniences to most of us. Perhaps the most helpful of these is refrigeration, but the electric washing machine, the electric iron, and the vacuum cleaner are not far behind. Electric cooking and toasting serve millions of pleased users. Air conditioning for the home is in its infancy, but will undoubtedly be much more common once the war is over. Electricity is the most versatile and the cheapest household slave we have ever had.

The demand for copper for electric uses multiplied many

fold when the commercial development of the use of electricity began in the early eighties. The copper produced in the United States in 1880 was about 30,000 short tons. By 1888 it had passed 100,000 tons. It reached nearly 200,000 tons in 1895, and before the first world war exceeded 600,000 tons. In 32 years its use had increased 20 fold and more. From 1880 to 1939—60 years—the world's production of copper increased from 173,000 short tons to 2,443,000 short tons—fourteen times. The United States led in its speed of putting the new slave to work, and in producing the copper from which his harness was made.

Another job for which electricity, with its copper harness, was found to be well fitted was communications, the broad field that began with the telegraph, then added the telephone, and now the radio. We celebrated just recently the hundredth anniversary of the sending of the famous message, "What hath God wrought," as the first communication ever to go by telegraph in 1844. To attempt to tell of the spread of the network of telegraph and telephone wires and cables of iron and copper, and of radio waves over the whole world and its effect on mankind would call for the skill of a super Homer. Suffice it to say that for our present purposes it is another in the long list of the developments in the use of natural resources for the peacetime use of man. And yet, like all other peacetime uses, it performs a most necessary service in war. If Napoleon could have summoned his reserves by telegraph or radio, and if they had arrived, Waterloo and the entire course of subsequent history might be a wholly different story than the one we now know.

In 1876, the telephone was first demonstrated at the centennial exposition in Philadelphia. Now the human voice could go over a wire for the first time. The result has been another network of wires and cables all over the world. Again the services of Mr. Super Homer are needed.

The Western Electric Company has prepared a list of

minerals needed in the manufacture and use of the telephone. Copper is, of course, the chief electric conductor. Iron is used in magnets; platinum in switchboard lamps; gold, platinum, and silver are used in contact points; lead in cable covers and fuses; antimony to harden the lead cable covers; tin in solder; nickel to plate parts and protect from corrosion, zinc to galvanize iron; coal, as granules in the transmitter; mica for insulation; aluminum in the diaphragm; and asphalt as a finish on the transmitter, and the cable terminals. Each one of these minerals, even the gold and platinum, is chosen to give the cheapest and most effective service.

As the newest instrument for communication electrical transmission of wireless signals was put into use in 1896 by Marconi. The final harnessing of the resources of coal, iron and copper, with the same long list of auxiliaries that serve in the telephone, has cheapened and extended communication beyond all comparison with the telegraph and the telephone. Now the soldier in the front line talks to his command post with his "Walkie-Talkie" and relates the current course of the battle. You and I sit down in the evening and in a short quarter hour hear direct voice reports from observers in London, Italy, China, the Philippines, and Washington. We can talk directly with our sons and brothers in the South Sea Islands, or we can listen to the finest orchestras and operas as we choose. Few places in the United States are so remote from broadcasting stations that people cannot get the latest news or the addresses of public men, or the music they prefer. We can sit beside a box filled with a complicated arrangement of many different natural resources and see something as it is happening even though the events take place many miles away. Again page Mr. Super Homer.

We also captured another husky slave, petroleum, a little before the time we put electricity to work. Like other

unfamiliar resources, it had to go through a period of testing to see what jobs it could do best. The first use that required large quantities was for lighting. When kerosene was ready to serve us the best light people had was the candle, except in the few cities which had gas lighting systems.

Petroleum was first produced in the United States in 1857, when 2000 barrels were sold. According to the figures of the Bureau of Mines, by 1870 the world production reached 5,790,000 barrels per year of which the United States produced 5,261,000 barrels. In 1880, the world produced 30 million barrels of which over 26 million were produced here. In 1900, while lighting was still the big job that petroleum did for us, before there were any appreciable number of automobiles to be served, world production was over 149 million barrels of which we produced about 43%.

Gasoline was for the most part, a product in little demand. To be able to sell it the refiners left as much as they could in the kerosene and disposed of the rest of it for what they could get. This led to so many disastrous lamp explosions that practically all states had official oil inspectors to insist that gasoline be kept out of kerosene. Statistical Abstracts for 1882 gives some interesting figures that illustrate these early conditions. In 1870, the United States produced 5.4 million gallons of gasoline and naphtha which brought the refiners a little less than ten cents a gallon on the average. They produced 97.9 million gallons of illuminating oil, which they sold for over 30 cents a gallon. In 1880, production was nearly four times what it was in 1870, with the gasoline selling for about six cents a gallon and kerosene for a little less than nine cents a gallon average at the refineries.

Petroleum did its lighting job so much better than any other means that from 1860 to 1900 world production was multiplied nearly 300 times—from 509,000 barrels to

149,137,000 barrels. But its use was still only a moderate portion of its capabilities. It was, you may say, patiently sitting there waiting for the internal combustion engine to be developed so it might really show what it could do.

When the automobile came into extensive use by 1910, world production was over 327 million barrels, of which the United States produced 299 million. In 1920, '30, and '40, United States production was nearly 443 million, over 898 million, and over 1,353 million respectively. These great increases were in spite of the fact that electricity had taken over much of the lighting job.

Two other metals of our natural resources became of importance in the closing years of the last century, nickel and aluminum. Nickel had been known for centuries, but had not found much use until its value as an alloy metal with steel was discovered. In 1880, the world used only 600 tons. Consumption increased to 3,100 tons in 1890, 10,400 tons in 1900, 25,500 tons in 1910, and to 34,000 tons in 1920. In 1930 it was 59,800 tons and in 1939 it had soared to 133,400 tons. Figures for 1940 and later years are not available because of the war, but production is known to have been the largest on record. In 1938, Canada produced nearly 83% of the world total. The price of the world's nickel in 1939 was a little under thirty cents a pound.

When Canada first started to produce nickel in 1890, the world was plentifully supplied by the French nickel mines of New Caledonia. But the Canadian deposits were the largest and permitted large scale cheap mining, so they soon demanded and received a place in the world's market by the customary means of a lower price. The situation was met by the Canadian producer by intensive scientific research to find more effective uses, and to prove to consumers that these uses could be most cheaply supplied by the use of nickel.

Aluminum was recognized by chemists as a very abundant

light-weight metal in the early part of the 19th century. It was successfully made in the '50's, but remained essentially a scientific curiosity until an American college student succeeded in finding a way to produce it cheaply in 1886. Hall worked at the problem before his graduation from Oberlin in 1885, and continued his research for eight months afterward before success was attained. The next three years were spent perfecting his process and interesting capital. In 1889, manufacture started. By 1895, the world production had reached 1000 tons per year which the producers sold for an average of 58.7 cents per pound.

The problem was to find uses for the new metal—some way in which it could be harnessed for the service of mankind. The producers studied its various properties and found it was a good conductor of electricity, but that its tensile strength was not sufficient to hold on the required long spans. This was overcome by using steel wire strands for strength, and so aluminum became a competitor of copper for transmission lines. Aluminum was found to be ideal for cooking utensils, it is light, easily formed into desired shapes, and transmits heat more efficiently than iron. The difficulty found, however, was a great one—the unwillingness of the public to adopt something new. The producers were equal to the need. They organized widespread sales activities and successfully overcame public inertia.

When the automobile came into the picture, aluminum found many uses, as pistons, crankcases, body sheets and every place where its lightness and other qualities fitted. It was almost wholly as an alloy that it found its uses.

The airplane, up to the tremendous numbers used in the present war, was not a great user of aluminum. But now, when the United States alone turns out planes at the rate of a hundred thousand per year, the demand for aluminum has gone way beyond the past.

Before this war started, aluminum was sold by the producer not only as pigs, bars, and sheets, but also in the form of sand and die castings, screws, bolts, rivets, collapsible tubes, wire, cable, structural shapes, extruded shapes, powder for paint, bottle and glass jar tops, tubing, mouldings, shingles, roofing sheets, and furniture.

Aluminum has won its way to full recognition as a useful servant of mankind. Its production grew rapidly.

TABLE IV
World Aluminum Production

| *Year* | *World Production of Aluminum* |
|---|---|
| 1895 | 1,000 short tons |
| 1900 | 7,000 " " |
| 1910 | 48,300 " " |
| 1920 | 140,800 " " |
| 1930 | 293,300 " " |
| 1940 | 885,100 " " |

In 1944, we see newspaper despatches indicating that productive capacity in the United States alone is great enough to make a million tons a year.

The latest metal to apply for a position as one of our useful slaves is magnesium. It is still going through the preliminary stages of finding out the jobs it is best fitted for. It has been produced in small quantities for more than 25 years. The Bureau of Mines gives production of 142 tons in 1918, but not again until 1925 did the yearly production reach 100 tons. In 1927, it reached 183 tons.

Magnesium is not quite two-thirds as heavy as aluminum. So far it has found its chief use as an alloy of aluminum, where the resulting piece is lighter than pure aluminum or other aluminum alloys. But the difficult task of finding the most suitable jobs for magnesium is still largely to be done. We have not learned enough yet to put this slave to work at maximum capacity.

In addition to the new uses found for the various metals,

two ancient slaves, gold and silver, were multiplied greatly and in timely fashion. The gold discoveries in California came at a time when they were of the greatest help in providing capital for the building of railroads and the accompanying extension of the telegraph lines and other business. Up to 1928, California had produced nearly 1,950 million dollars in gold.

Australian gold discoveries followed soon after those of California. These had added, up to 1928, over 3,000 millions of dollars, to which two other British Dominions, South Africa and Canada, had added by the same date, over 4,200 millions and over 580 millions respectively. These all total about 16.8 billion dollars at present values of $35 per ounce.

The United States Bureau of the Mint estimates that from 1493 to 1939 the total gold production of the world was valued at about 30.5 billion dollars, and the silver at about 15.4 billion dollars. It is an interesting comparison of size and value to note that this 30.5 billion dollars of gold would about fill a moderately large house. It would equal a cube of gold about 42 feet on a side. In relation to the estimated 30.5 billion dollars of gold produced since the discovery of America, it is interesting to note that the world's gold reserves held by central banks and governments at the end of 1940 amounted to 30.5 billion dollars. In other words, the equivalent of all the billions of gold recovered before 1493 is lost, or in private hoards, or in jewels.

These vast billions of gold and silver have been a very important factor in making possible the tremendous development of business in the industrial revolution. Undoubtedly without them, and the multiplication of their monetary effectiveness by the devices of paper money and bank credit, the progress we have made would have been notably slower.

There is a most interesting similarity in the commercial history of the various great uses we have found for our chief

natural resources in the last 125 years, and the great gold rushes that followed important discoveries. Inventors, engineers, and scientists labored with a problem first, each hoping to find something that would give him both a great personal satisfaction in his accomplishment and a large monetary reward. These men labored to develop and train these slaves, natural resources and natural forces, so that they could perform valuable work for mankind and then to sell them to the public.

Men of this class were Trevithick, George Stephenson and his son Robert in England, and Stevens in the United States who made the power of coal and iron available for transport use in the steam locomotive; Bessemer who made good steel a common cheap commodity; the numerous group that harnessed electricity such as Thomson and Edison; Bell, Blake and others who brought the telephone out of their imaginations, and made it so universal a servant; or the Wright brothers who gave us the airplane.

These men were often times more interested in the doing of the job and better qualified to do it than they were in the making of the money that would reward good management and service to the public. Most of them had devoted their efforts throughout their lives so exclusively to dealing with the materials and forces with which they worked, that they had not had time to devote to learning the ways of successful business. Their inventions made greater opportunities for money making than the greatest gold field ever discovered. Many people who wanted to "get rich quick" were attracted to the new fields of endeavor which their inventions made possible, just as similar people with similar desires were attracted to the goldfields of California in '49. These men were of all kinds, and included at least average proportions of those who were willing to profit by sharp practices. From these circumstances came the disgraceful financial events that gave color to the early days of railroad

and oil development in this country and the many similar events in other industries.

But, whether they knew it or not, all of these men, good and otherwise, were contributing to developments that made this country of ours the greatest and most prosperous that the world has ever known. The evils of stock-jobbing, of selling counterfeit stock certificates, of promoting fake enterprises and pocketing the money of the gullible were far outweighed by the good that was accomplished. Such practices made the epithets of "big business" and "economic royalist" something for the politician to conjure with, as well as the basis for more statesmanlike regulatory legislation. These unethical practices of a small part of the developers of industry have given many people the unwarranted notion that all business is bad, and deserves to be done away with, even though the evil things of the early days have so largely been eliminated. Crime is screamed in the headlines, while the thousand fold more numerous deeds of honest men are performed without making the news.

The code of ethics of business has developed and improved since the early days of the industrial revolution, and the piratical spirit has been greatly curbed and lessened. But wherever and whenever new developments occur that make "easy money" possible, there will be plenty of people willing to grab it by whatever method may offer greatest returns, ethical or otherwise. This was well illustrated by the bootlegging era that followed the passage of the 18th Amendment to the Constitution, and the gangsters whom that period of easy money brought into activity.

While we have made somewhat of a mess of it at times, we have on the whole done a wonderful job of taming the forces and the resources of nature to supply us with wealth of food, clothing, shelter, transportation and communication facilities, as well as the delights of the arts, the theater, music, painting and sculpture, undreamed of by any large

group of men heretofore in all history. Many necessities and luxuries that a hundred years ago the wealthiest could not have, are now possessed in abundance by almost everybody.

If we have the good sense and understanding to realize this and to go ahead wisely, there is no imaginable good for the whole people that we cannot accomplish. Our United States communication and transportation systems have eliminated from our land the possibility of that dread scourge of ancient peoples—famine. It has mitigated catastrophes of all kinds. A flood, or a great fire, or a tornado, or even an epidemic is not followed by the long and widespread suffering that used to be the inevitable consequence of such disasters. In such cases the Red Cross has only to rub its Aladdin's lamp and the trained slaves, our natural resources of coal, oil, iron, copper, aluminum and others, immediately carry in abundance the needed help and supplies to those affected.

## CHAPTER 4

# Present Sources of the World's Metals

BOB: Dick and I promised to ask all the questions we could think of on this trip. We haven't asked many so far but we decided this morning that we'd make up for our silence by asking a big one. We'd like to have you tell us more about the whole list of natural resources. We have known something about all those mentioned so far, gold and silver, iron, coal and oil, copper, tin, lead, zinc, nickel, aluminum and magnesium, that are used in quantities. There must be lots of minor ones we have never heard of. We'd also like to know something about where they come from, where they are used and what for.

Mr. Hotchkiss: You surely have made up for lost time with this question. It would take a large library to answer it in full, but I think some of the high lights may be of interest. Suppose we discuss the metals first and then later take up coal and oil and the other non-metals.

Few metals are found in nature in metallic form. All metals are found in nature combined with oxygen, sulphur, silica or other less common chemical mates. Only gold, silver, and copper are found in the native metal state so abundantly as to warrant mining operations. By far the most of the gold occurs as the metal. Silver comes mostly from ores in which it is a sulphide or chloride. Most of the worlds copper is found as copper sulphides. None of these ores is found in great deposits of pure form. They are always mixed with other and valueless minerals so that they usually have to be separated or "concentrated"

before they are ready to go to the smelting furnace. Iron ores are the great exceptions to this rule. Most of those that are now used are rich enough to go directly from the mines to the furnace without undergoing a concentrating process.

A copper ore with 10% of the metal in it is an exceedingly rich ore. Most of the world's copper comes from ores that have less than 3% of metal in them. And the world's greatest copper mines now work ore that has less than 1% of copper. Fifty years ago such lean material could not have been worked profitably and so would have been only an interesting but economically valueless occurrence of copper material.

Before an occurrence of mineral can be worked as an ore, someone must need the metal it contains badly enough to pay a price that will pay someone a profit for mining it. So all the conditions must be such as to make this possible. What would be a rich copper ore deposit in Utah would be valueless under present conditions if it were situated at the south pole. Nearness to market, proper transportation facilities, the availability of a cheap process for concentrating the ores, for reducing them to metal, suitable living conditions, market prices, and many other factors enter into the decision as to whether there is a profit to be made.

A mineral occurrence with a certain percent of metal may be ore in one place but not in another. It may not be ore at one time, but with changed conditions, such as the making available of transportation facilities, or the increase in efficiency of methods of working, or the development of a new and cheaper process it may become a valuable ore body. As rich ores are mined out, from which cheap production is possible, leaner and hitherto unprofitable ores may find a profitable market on account of increased prices.

So in thinking of where our ore supplies come from it must always be remembered that ALL present ore bodies will be worked out some day, many of them at so early a day as to

be distressing. If we are to continue to have metals either new ore bodies must be found, or we must get them from deposits too lean to be used now and for which we must invent new ways to make them useful, or we must pay a higher price.

With these thoughts in mind we can take up the various metal resources and see where the world gets its supplies of those useful slaves that make possible our present way of living.

### *Iron Ores of the United States*

The greatest producer of iron ore is the United States. The region we shall see in a few days—the Lake Superior District—produces about 85% of the United States present output. It is by far the most important source of iron ore in the world at the present time. The greatest factor in this district is the Mesabi Range. During the recent war years it has produced nearly three quarters of the total ore shipped from the Lake Superior District.

When we drive up from Duluth to the Mesabi Range you two boys will see sights not equalled elsewhere in the world—great open pits where approximately a billion tons of ore have been removed. Now it is being mined by huge electric power shovels that load a seventy-five ton railroad car in 7 to 10 scoops of their big dippers. In 1943 one great open pit produced more than 24 million tons—more ore than has ever been mined in a single year in any country in the world excepting France and the U.S.S.R. Nowhere else will you find such enormous operations in mining iron ore, and no operations that so cheaply put iron ore in cars ready for shipment. You will see in many pits smaller shovels working, cleaning up smaller pockets of ore left after the great mass of the ore has been taken out. These are very significant. They are the last sweepings of some of the great ore bodies. They are proof that sooner or later all ore

bodies are worked out and no longer add their quota to fill the needs of the country.

The cheapness of this open pit mining compared to underground mining is indicated by the amount of ore produced per man-hour of work for every man employed about the operation. For the year 1939, before the war in Europe had begun to affect our iron mining industry appreciably, the average tons produced per man hour in the underground mines of Alabama was 0.66. In Minnesota underground mines, where the ore bodies average larger than in Alabama, the average was 0.8 tons per man hour. The average ton of iron ore per man hour for the whole country was 1.3 tons because about two thirds of the iron ore mined in the U. S. was from the open pits of Minnesota, where the man hour rate was 3.5 tons. The average man working about a Minnesota open pit mine produced in 1939, a fair average year, about four and one half times as much as a man working at an underground Minnesota iron mine and nearly six times as much as the Alabama mine worker. These figures do not indicate relative diligence of the miners. They represent the fact that some iron ore bodies are large enough and sufficiently close to the surface so that the great shovels and trucks and railroad cars you will see can be used efficiently. Such massive machinery cannot be used in an underground mine. The work there must be done with smaller, less efficient machines. Furthermore most of the underground mines in the Lake Superior district and elsewhere are much deeper than the open pit mines some are more than 3000 feet deep—and the labor of hoisting the ore to the surface is greater.

In the Mesabi Range, where the big open pit operations lie, the ore bodies are big in horizontal dimensions, like great, wide lima bean pods lying flat. In the other Lake Superior ranges these pods are neither so large nor do they lie flat. They lie at steep angles as though the lima bean

pods had tilted, or even turned on edge or on end, and are more irregular in shape. In Alabama the great thin ore beds are tilted up less steeply, but enough so that underground mining methods are necessary except in rare situations, where a small tonnage may be mineable with big mechanical shovels.

The fact that so much of our iron ore comes from the Mesabi Range open pits was a very fortunate one for us. The double normal demand for iron ore, caused by war needs, could not have been supplied if we had been dependent on ore from underground mines. It takes years to sink the shafts and drive the extensive access workings in an underground ore body to bring it into full production. It is relatively simple and vastly quicker to multiply the number of power shovels in an open pit mine. Furthermore a number of great ore bodies on the Mesabi had long ago been stripped of their cover of glacial drift, the sand, gravel, clay, and boulders that the great continental ice sheets had left covering the ore when they melted away. This stripping left great ore bodies ready for putting in railroad tracks and for setting the great shovels to work loading ore with little delay. For this reason we have been able to ship approximately 90 million tons a year from Lake Superior to the furnaces to meet our urgent necessities of the war years.

Without these ore bodies, already stripped and ready to mine, we could not have produced the steel necessary to build nearly so many of the tanks, and ships, and guns our fighting men and our allies are using so effectively to win the war. The outcome might have been much more doubtful, and success would surely have been longer delayed and more costly in lives.

This ore, so fortunately ready for the hour of necessity, was not prepared for this emergency because of wise planning. Rather it must be called a costly business mistake. In the decade before World War I began, the increase in

demand for iron ore was so rapid that owners of these ore bodies spent millions of dollars in stripping off the glacial drift that covered the ore, thinking that there would be demand for it as soon as they could be ready to ship. But the need for ore was not so great as had been estimated, so these ore bodies lay there unused until World War II came along and needed them so badly. They were literally "life savers" for us, for it is certain that it would have meant the sacrifice of many more of our soldiers lives if we had not had these ores in shape to use without delay. We can well bless the mine owners of 35 years ago for making a mistake that caused them the loss of many millions of dollars.

Mr. Banker: You have told us about the Lake Superior district. How about the other iron ore districts of the country. Will they be able to supply our needs when the Lake Superior ores are gone, and what are they producing now?

Mr. Hotchkiss: The question of reserves of iron ore for the future I had planned to discuss at a later session. This is a very important matter and I think we will get a better picture of the situation if we discuss all the reserves together. So with your permission I will confine my answer to production of the other regions.

In 1939, which we can accept as a fairly normal year, we find the Lake Superior district produced 42 million tons of iron ore averaging better than 52% iron. The next largest producer was Alabama which furnished nearly 6 million tons of ore analyzing 36% iron—the lowest iron content of any large U. S. producer. Next came the Northeastern district which includes Pennsylvania, New Jersey and New York. This district produced a little more than 3 million tons. Practically all of the Northeastern ores are magnetite. Those from New York were concentrated to 66.8% iron, and New Jersey ores to 63.3% iron. The Pennsylvania ores averaged 40.2% iron.

The fourth producing area groups all the western ores. These totalled 917 thousand tons in '39 of which Wyoming's share was 588 thousand and Utah's 262 thousand. California, Missouri, South Dakota and Washington together produced the remaining 67 thousand tons of western ore.

These figures serve to emphasize the outstanding importance of the production from the Lake Superior district. The world's next largest producing country, France, produces normally between half and three quarters as great a tonnage as Lake Superior but the ore is much lower grade. But in the years of the depression following 1929 French production kept closer to its normal tonnage while Lake Superior dropped to less than half normal. In those years French tonnage exceeded that of Lake Superior. In most of these low years, however, the actual total tons of metallic iron in the Lake Superior ores exceeded that in French ores.

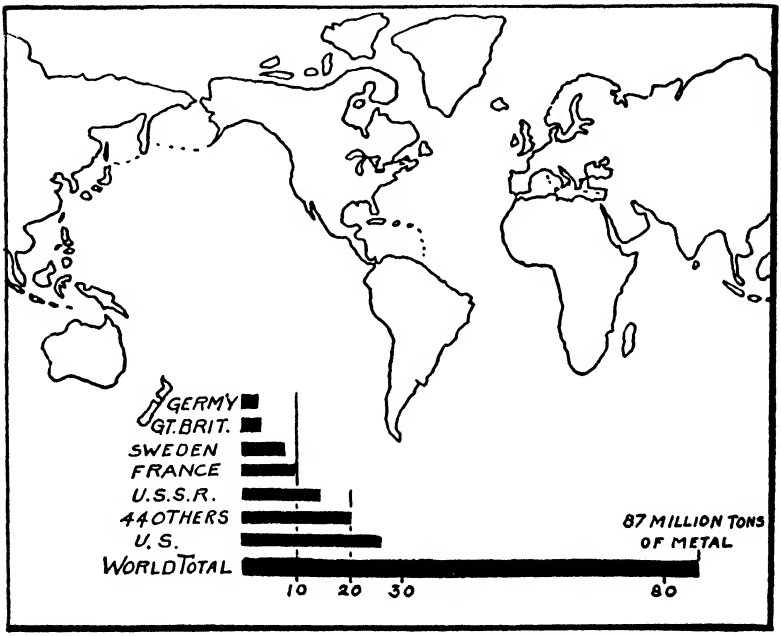
As Mr. Banker implied in his question this primacy of the Lake Superior district must be looked upon as a statement of conditions that prevail at present. What may be the case 20 years, or even 10 years from now you steel men would like to know. So would every other man interested in the future prosperity of our country. That discussion will be deferred to a later session of our forum. It is enough to say now that the outcome depends largely on the energy and skill, the organizing ability and capital that the industry devotes to the matter. What will happen will be to a great degree what far-seeing men determinedly make happen.

### *World Iron Ore Production*

Bob: Dick and I have studied those figures you gave us and made two charts showing the production of iron ore and steel by the larger producers. We have not shown tons of iron ore, but instead we have shown the tons of iron metal in the ore. In this way the low grade ores are made to compare fairly

with the high grade ores. If you are ready to discuss iron ore production Dick and I will hold them up.

Mr. Hotchkiss: Thank you boys, you have done a good job, and the charts will help us all.




*World Iron Ore Production in* 1938 *or* 1939, *given not as tons of ore but as tons of metal in the ore.*

The world's production of iron ore comes from many countries scattered in every continent. The U. S. Bureau of Mines, from which these figures are taken, in 1940 listed 51 countries and possessions as producing iron ore. Among the 32 countries producing less than a million tons a year, these varied from Tasmania, the smallest, with only 62 tons reported, up to Japan with 755,000 (1936), the Philippines, with 910,000 tons, and Italy with 990,000 tons.

These 32 countries in 1938 produced a total of 8.7 million metric tons.

Then come six countries that produced between 1 and 2 million tons each. These six, Newfoundland, Chile, Czechoslovakia, Norway, Unfederated Malay States and Spanish Morocco, produced a total of a little over 9.5 million metric tons.

TABLE V

World Iron Ore Production and Metal Content

Metal Content for countries other than U. S. is from "World Minerals and World Peace," Brookings Institution.

| *Country* | *Million Metric Tons of Ore* | *Iron Metal Content Million Metric Tons* |
|---|---|---|
| United States | 52.6 | 26.4 |
| *France | 33.1 | 10.1 |
| *U.S.S.R. (includes Siberia) | 26.5 | 14.6 |
| *Sweden | 13.9 | 8.4 |
| *Great Britain | 12.0 | 3.6 |
| *Germany | 10.9 | 3.1 |
| *Luxemburg | 5.1 | |
| British India | 3.1 | |
| Algeria | 2.8 | |
| Australia | 2.6 | Note: Metal Content included in "Others" |
| *Austria | 2.6 | |
| Spain | 2.3 | |
| *Others: | | |
| 6 countries between 1 & 2 million | 9.5 | |
| 32 countries less than 1 million | 8.7 | |
| Total others | 18.2 | 20.5 |
| Grand total | 185.7 | 86.7 |

There were 12 countries producing over 2 million metric tons each in 1938 or 1939. In Table V the production for

these 12 is given in metric tons of 2204 pounds for the year 1939, or for 1938 where indicated by a star.

These figures will not please those who dislike to mix productions of different years to get a total. I have done it after deliberation for the reason that I believe it gives a better picture of the normal world iron ore situation before it was materially affected by the war.

A number of interesting and important facts lie more or less hidden in these figures. I want to call your attention to a few of them.

The U. S. iron ore production averages a trifle better than 50% in iron metal content. The iron ore of the rest of the world averages only 45% iron. The iron ores of the second largest producer, France, (and Luxemburg as well) average only 30% iron. German iron ores in 1938 averaged only 28% iron. English ores also are of this same low grade—30% iron.

Of the large producers of European iron ores only the U.S.S.R. with 55% iron content and Sweden with a little better than 60% iron, can compare with Lake Superior ores in quality.

In world iron ore production the United States and Europe are overwhelmingly dominant factors. Grouped by continents the world's production of 185.7 million tons was in order of tonnage:

| | | |
|---|---|---|
| Europe.................. | 113.5 | million metric tons |
| North America.......... | 54.5 | " " " |
| Africa.................. | 6.9 | " " " |
| Asia.................... | 6.5 | " " " |
| Oceania................ | 2.3 | " " " |
| South America.......... | 2.0 | " " " |
| | 185.7 | " " " |

If we were to divide the world iron ore production between northern and southern hemispheres we would find only

about 6.4 million tons are produced south of the equator, or about 3.5% of the 185.7 million tons.

These facts are elements of vital importance in the distribution of political, commercial, and military strength among the nations of the world. If we were to divide the 185.7 million tons of iron ore production between the Axis nations and the Allies we would find that in 1938 the Axis controlled 40% and the Allies 60% of the worlds total. Of the Axis 40% Japan had only 2% and Germany (and Italy) 38%. It must be remembered that the war has put great demand on production elsewhere as it has in the United States so the actual war year figures would be as much larger than the 1938–9 basis as the Axis nations have been able to accomplish. It is doubted that this exceeds the '38 production greatly.

Dick: Do you want Bob and me to take down the iron ore figures and hang up the chart we made showing steel production?

Mr. Hotchkiss: If you will please.

Mr. Manager: Before that iron ore chart is taken down I think we should look carefully at those figures of the iron metal in the ores. I understand that you will take up the question of the worlds iron ore reserves later, and when you do these production figures should be in our minds.

Mr. Hotchkiss: We can refer back to this chart whenever you want to. All right boys, show us the steel production chart you have made.

### *World Steel Production*

The steel production of a country is not necessarily parallel to the iron content of the iron ores it produces. Iron ore tends to move to coal. Since it takes two or more tons of coal to reduce a ton of iron ore and work the metal into saleable forms it is cheaper to freight ore to coal than to

freight coal to ore. The great steel districts of the world are therefore in or close to coal areas.

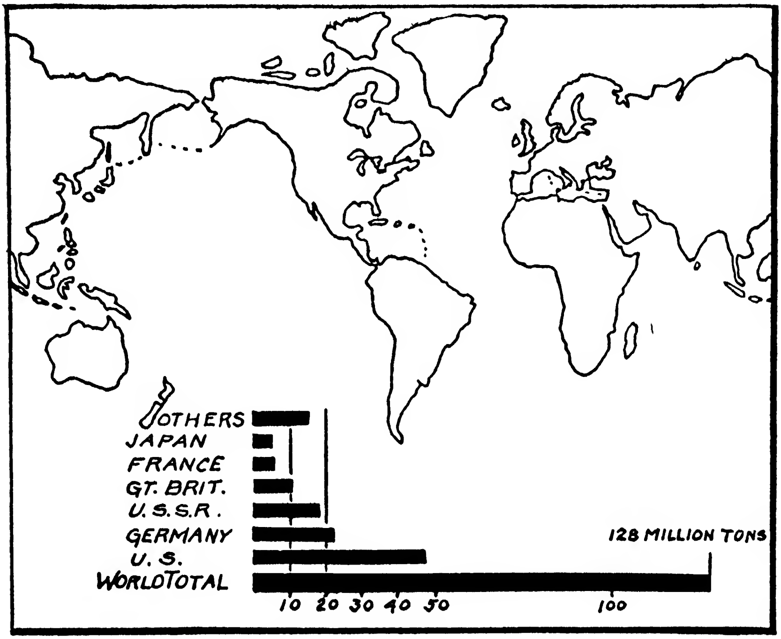
If we take the iron content of the iron ores produced by various countries as shown on table V and set beside each country its steel production it is evident at once that the ore moves to coal.

TABLE VI
World Steel Production
(In millions of metric tons)

| *Country* | *Iron Metal Content of Ore Produced 1938 or 1939* | *Steel Production* |
|---|---|---|
| United States | 26.4 | 48.0 |
| France | 10.1 | 6.2 |
| U.S.S.R. (including Siberia) | 14.6 | 18.4 |
| Sweden | 8.4 | |
| Great Britain | 3.6 | 10.6 |
| Germany | 3.1 | 23.2 |
| Japan | .5 est. | 5.9 |
| Others | 20.0 | 15.6 |
| | 86.7 | 127.9 |

Looking at these figures, Bob and Dick, you might well ask how we made 48 million metric tons of steel in 1939 when there was only 26.4 million tons of iron in the ore we produced. You could look at the figures for the other countries and ask similar questions. You could well think we had to import enough ore or pig iron to add to the ore we produced to make 48 million tons. As a matter of fact we did import some ore in 1939, but only 2.4 million tons, mainly from Chile, but with substantial tonnages from Cuba, Sweden, and Norway. We exported 1.4 million tons, almost all of it to Canada. We imported 43 *thousand* tons of pig iron, and exported 198 *thousand*, so that doesn't supply the answer to how we made 48 million tons of steel that year.

The way it was done was by the use of scrap iron. We used about 27 million metric tons of scrap in 1939 to make steel—more iron than there was in the ore we mined. We also shipped 4 million tons of scrap to Japan.




*World Steel Production in* 1938 *or* 1939.

The questions raised in your minds by Table VI with regard to other countries are answered by two facts. The country *imported most of its ore* as well as using scrap iron, as did Great Britain, Germany and Japan, or the country *exported much or all of its ore* to countries having coal, as did France, Sweden, and almost all the countries producing lesser amounts and listed in the ore column as "others."

If we were to divide the steel producing capacity of the world in 1940 between the Allies and the Axis nations we

would find Germany (and Italy) controlled about 30% and Japan 3.8%. The British Empire controlled 11.2% of which three quarters was in the United Kingdom and the rest in India ($\frac{1}{8}$) Canada ($\frac{1}{16}$) and Australia ($\frac{1}{16}$). Russia had 11.0% but part of this was in German hands. The United States had 37.5% of the world's steel capacity. Since 1940 the United States production capacity has been increased 30% or more over 1940 capacity, and it is doubtful if the other countries could effect much increase. If the world steel capacity is assumed to be 200 million metric tons in 1943—it was 175 million in 1940—a fair estimate of the division would give the Allies 70% and the Axis 30% of the world capacity.

Table VI shows where the world makes its steel. It also shows how great a part of the world's total is produced by the United States. In 1880 we were producing iron ore at the rate of 7 million tons per year, which contained probably about 3.8 million tons of iron. From 1880 to the end of 1941 we produced iron ore with 1,233 million tons of iron metal in it. Most of this metal is still here, in use, rusted away, or lost. How much of it is in use we have no accurate figures, but it is probably somewhat over a billion tons.

The uses made of steel are vast in number. It is doubtful if anyone could make a complete list that did not omit some use. The American Iron and Steel Institute prepared figures for principal uses in 1940 from which the following tonnages are taken. The figures are for net tons of 2000 pounds.

Will you boys put up the chart you have made showing the principal uses of steel in the United States?

Bob and Dick: Here it is.

Exports made the largest single item with one sixth. While we were not yet in the war we were actively beginning to serve as the "arsenal of democracy." The greatest domestic user was the automobile industry which took over

a seventh. Jobbers, dealers, and distributors together took nearly as much as the automobile makers.

TABLE VII

Principal Uses of Steel in U. S. in 1940

| *Industry* | *Net Tons* | *Percent* |
|---|---|---|
| For export | 8,099,000 | 17.7 |
| Automotive industry | 7,185,000 | 15.7 |
| Jobbers, etc | 6,687,000 | 14.6 |
| Construction industry | 4,968,000 | 10.8 |
| Railroad industry | 3,777,000 | 8.2 |
| Container industry | 2,985,000 | 6.5 |
| Steel converting industry, wire, bolts forging, etc | 2,929,000 | 6.4 |
| Pressing and stamping industry, hardware, furniture, etc | 2,160,000 | 4.7 |
| Machinery, tools | 1,885,000 | 4.1 |
| Oil, gas, mining | 1,132,000 | 2.5 |
| Agriculture implements, etc | 920,000 | 2.0 |
| Shipbuilding | 940,000 | 2.0 |
| Aircraft industry | 48,000 | 0.1 |
| Others | 2,136,000 | 4.7 |
| Total finished steel | 45,851,000 | 100.0 |

Mr. President: I think it is worth while to call attention, at this point, to the fact that the 1940 production of steel given in this table has been doubled since we got into the war.

*The World's Copper*

The United States is the world's largest producer of copper as well as of steel. We import much copper in the form of ore and unrefined metal, but we export in general rather more than we import. We consume the greater part of what we produce.

Will you boys now show us the chart with the uses of copper in the United States.

We use this copper for many purposes. In 1939 which

was a fairly typical year we used nearly a quarter of our copper for electrical manufactures. We used a third of it in three other ways, about the same tonnage for each, in buildings, in automobiles, and for rod and wire for other than electric uses. We used about one twelfth for light and power lines. These uses are shown in detail in the table which the boys have just hung up for us.

TABLE VIII

Uses of Copper in the United States in 1939

| | *Short Tons* | *Percent* |
|---|---|---|
| Electrical manufactures | 185,000 | 23.2 |
| Rod and wire for non-electrical use | 95,000 | 11.8 |
| Buildings (excluding electrical work) | 89,000 | 11.1 |
| Automobiles (excluding starter and generating use) | 85,000 | 10.6 |
| Light and power lines | 67,000 | 8.4 |
| Telephone and telegraph | 39,000 | 4.9 |
| Castings, valves, bushings, etc | 33,000 | 4.1 |
| Other uses | 108,000 | 25.9 |
| | 810,000 | 100.0 |

Among "other uses" for 1939 was 14,500 tons, or 1.8% used for ammunition. This presumably covered army, navy, and civilian uses. In 1942 and 1943 the amount of copper used for this and for other war purposes was so great that uses for non war purposes were either eliminated or cut to the barest minimum. "Other uses" in 1939 also included 27,000 tons used for radio sets.

If you have any further wonderment as to the uses we have for copper here is a partial list of "other uses," which called for the use of 108,000 tons of copper. About one half of this was used in making articles for export.

| | |
|---|---|
| Wire cloth | Valves in inner tubes |
| Clocks and watches | Jar tops and rouge boxes |
| Heating radiators | Flash light tubes |
| Railway equipment | Kerosene lamps |

| | |
|---|---|
| Refrigerators | Kitchen utensils |
| Shipbuilding | Range boilers |
| Air conditioning | Linotype matrices |
| Condenser tubes | Safety razors |
| Oil burners | Blasting caps |
| Nickel silver | Water meters |
| Phosphor bronze | Thermostats |
| Toilet pins | Soldering coppers |
| Eyelets and grommets | Yacht fittings |
| Electrotyping and engraving | Coinage |
| Spark plugs | Washing machines |
| Engines | Water heaters |
| Pumps | Fire extinguishers |

This list is long but it is not complete I assure you. I think any one of us, with a little thought, could name other uses we make of copper.

The war uses would add many to the above peaceful list. Not only would they add many uses but they have multiplied greatly the tonnage used for these purposes. The War Production Board stated that copper *supply* for the United States reached an all time high of 2,460,000 tons in 1941, and then was increased in 1942 to nearly 3,000,000 tons and added, "Despite a United States Supply of copper in 1942 greater than the entire known world output in 1939 and despite the shutting off of all copper to non-essential needs, production in many munitions plants was dislocated because copper was not available.

Beginning with 1880, in which we produced in the United States 30,000 short tons of copper metal, our production has grown rapidly. During the period of World War I for four years our production was nearly a million tons of metal a year. In 1929 it slightly exceeded a million. In this war it will be found to be much greater when figures are available. The great tonnages named by the War Production Board were not stated as United States *production* but as *supply*. They undoubtedly included imported copper.

If we add up the production figures from 1880 to 1941 we get the stupendous total production of over 28 million tons of copper metal. Some of this we exported, but by far the greater amount we kept and used ourselves. Some of this old production is now coming back as scrap to be remelted and used over again. The War Production Board stated that over 600,000 tons of refined copper was produced from scrap in 1942.

Over half the worlds copper in 1938 came from the western hemisphere—from the three greatest producers, United States, Chile and Canada as well as several smaller ones. Nearly another quarter came from Africa. The final quarter came from U.S.S.R., Japan, and many other smaller producers, none of which others produced 50,000 tons. Beside the countries named there is a long list of smaller producers; three others in North America, three others in South America, thirteen others in Europe, seven others in Asia, four others in Africa—a total of 41 countries.

Now will you boys give us the chart you have made showing the copper production of the world?

Boys: Coming up at once, sir.

TABLE IX

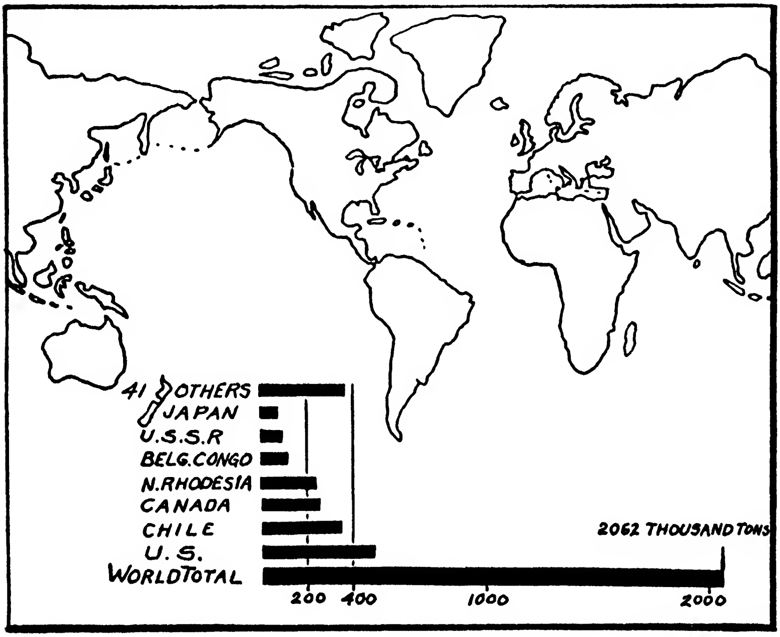
World Copper Production 1938. New Copper
(In metric tons (2204 pounds))

| | | *Percentage* |
|---|---|---|
| United States | 506,000 | 24.5 |
| Chile | 351,000 | 17.1 |
| Canada | 259,000 | 12.6 |
| N. Rhodesia | 255,000 | 12.4 |
| Belgian Congo | 124,000 | 6.0 |
| U.S.S.R | 102,000 | 4.9 |
| Japan | 81,000 | 3.9 |
| Others | 384,000 | 18.6 |
| | 2,062,000 | 100.0 |

The fact that the total tonnage of copper produced from domestic sources in 1939 was only about one fiftieth the

tonnage of steel is apt to give a wrong impression of the relative importance of the two metals.

To produce the steel we mined 55 million long tons of iron ore. To produce the copper we mined almost the same tonnage, over 49 million long tons of copper ore. About




*World Copper Production in* 1938.

65% of the iron ore was mined in open cuts, or pits, by great mechanical equipment. Probably about the same or a bit larger percentage of the copper ore was mined in open cuts, with the same kind of heavy, efficient equipment.

The iron ore had a metal content of 52% while the copper ore had only 1.2% metal. The steel production was made by using scrap weighing 55% of the total steel produced.

The copper produced from domestic materials was more than 41% from scrap.

In value the two metals are far apart. Copper is sold as refined metal and in 1939 its average price was 10.4¢ per pound. If all domestic production, new and old, had been sold for this price its value would have been $253 million.

Steel is sold in various forms and so there is no exactly comparable basis. But if all steel had been sold in 1939 at the average price of finished steel, 2.257 cents per pound, its total value would have been $2,386 million.

Our total copper production in '39 was about $\frac{1}{50}$ the tonnage, 5 times the price per pound, and $\frac{1}{10}$ the value of the total steel production in that year.

### *The World's Lead*

It is pleasant to report for another metal that the United States is the world's largest producer, with nearly a quarter of the world's lead to its credit in 1939. Since 1900 we have imported more lead than we have exported excepting in seven different years, five of which were the World War years 1914 to 1918 inclusive. We import foreign ores, silver-lead bullion for refining, and a moderate amount of metal pig and manufactured lead products. But we use a little more lead than we produce from domestic sources.

In 1939 the United States produced from domesitc ores 421 thousand tons of new lead. In addition we recovered old lead from scrap amounting to 241 thousand tons. This total production of 662 thousand tons supplied almost completely our 1939 consumption of 667 thousand tons. So we needed to withdraw from stocks, or to retain from imports only 5000 tons to meet our needs.

That consumption of 667 thousand tons was used in a great variety of ways. Nearly half of it was used for purposes that didn't exist 50 years ago, including the greatest use of all—storage batteries.

Will you boys hang up the chart you have made showing the uses of lead?

Boys: It is right here.

Mr. Banker: I am glad you have had the boys make these charts. They will remember them better that way.

Mr. Hotchkiss: The Bureau of Mines gives very complete figures on these uses, from which the table is taken.

TABLE X

United States Uses of Metallic Lead in 1939 in Short Tons

| | | | |
|---|---|---|---|
| Storage batteries | 198,000 | Calking | 16,000 |
| White lead | 75,000 | Type metal | 14,000 |
| Cable covering | 74,400 | Bearing metal | 12,800 |
| Red lead and litharge | 57,200 | Automobiles | 8,900 |
| Building | 50,000 | Castings | 7,500 |
| Ammunition | 42,300 | Terneplate | 6,000 |
| Foil | 21,800 | Other uses | 63,100 |
| Solder | 20,000 | Total | 667,000 |

The war years have brought greatly increased needs for lead. In 1940 consumption went up to 782,000 tons. The War Production Board gives our rate of supply from both domestic and foreign sources at the end of 1941 as 1,339,000 tons and at the end of 1942 as 1,308,000 tons. War vehicles of all kinds require a much greater tonnage than in 1939. While the military needs required restriction of civilian uses lead was the one important metal in which shortage was not serious at the end of 1942. The War Production Board encouraged production by offering premium payments of $2\frac{3}{4}$ cents per pound above regular price for all production over the ordinary production quota.

An interesting indication of war preparation and use is the Japanese import of lead. Japan produces ordinarily from 4000 to 10,000 tons of lead per year, and imports the remainder of her needs. In 1939 her imports increased to 43% more than in 1933, to a total of 106,000 short tons. The United States exported to Japan, from 1934–37, an

average of 8400 tons. In 1938 Japan ceased to report its mineral statistics and put the use of lead under government restriction. Our exports of lead to Japan jumped to 30,203 tons in 1938, and to 34,790 tons in 1939.

The price of lead in 1939 in the United States averaged 5.05 cents per pound, not far from the average price for 40 years. At that price the 667,000 tons we consumed cost us $67,367,-000, about one quarter of what our domestic copper sold for, or about one thirty-fifth of what our steel production sold for.

If we add all the production for the years from 1880 to 1941 we find a total United States production of refined lead from domestic ores of 21,062,000 tons. This great quantity is just about what we have used, since our exports and imports of lead have approximately balanced. The part that has been used as white lead and other paint pigments has disappeared. The part that has been used as metal is either still in use or has been wasted. Since it is probable that nearly a quarter of the total has been used as pigments there is perhaps 16 million tons either in use or wasted. Possibly there is about 12 million tons actually in use, much of which will some day come back into market as secondary, or scrap, lead.

Lead has long been an important, much used metal. Back in 1880 we produced about 100,000 tons, when the copper we mined was only 30,000 tons. The Bureau of Mines has estimated the total United States production of primary refined lead for 220 years from 1720 to 1940 inclusive as 22,871,000 tons. From the end of 1918 to the present, in the years since World War I, we have produced more than half this amount. In the last 24 years we have produced half of what we produced in 224 years. Our consuming pace has speeded up, we may well say, "terribly."

The world's production of lead in 1939, given in metric tons, was 1,741,000 tons. Almost exactly 90% of this was from the 12 countries reported as producing 20,000 tons or

more each. North America was the source of 46% of the world's total. The British Empire was the source of 30%. Countries held by Germany in 1942 or tributary to it, produced 453,000 tons in 1939—26% of the worlds total. This unsatisfactorily small part of the world's total compelled Germany to seek every way of expanding production and also to restrict use of lead for civilian purposes. One interesting result of this is research by the Germans to develop a storage battery that requires no lead or a reduced amount of lead. If this is accomplished it will help to conserve our diminishing lead supply after the war is over.

Now we are ready for your chart of the world's lead production.

Dick: Here it is.

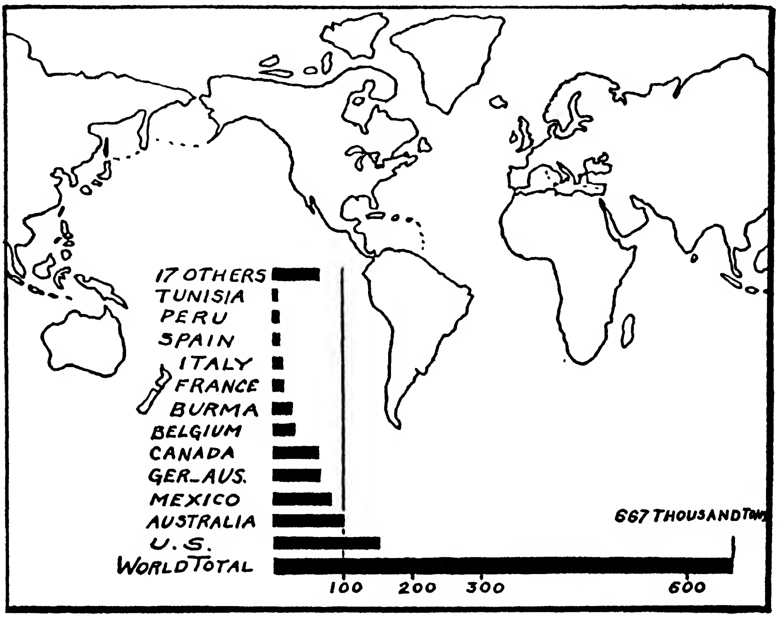
Mr. Lawyer: These charts are convincing evidence that the United States is a "have" nation, not one of the "have nots." I hope this condition can last forever.

Mr. Hotchkiss: We are truly fortunate in our abundance of natural resources. But we shall see later that there are resources that we lack in most serious degree.

TABLE XI
1939 World Lead Production
(In metric tons)

| | | |
|---|---|---|
| United States | 404,257 | 23.3% |
| Australia | 269,590 | 15.5 |
| Mexico | 219,300 | 12.6 |
| Germany-Austria | 181,400 | 10.4 |
| Canada | 172,880 | 9.9 |
| Belgium | 82,000 | 4.7 |
| Burma | 77,200 | 4.4 |
| France | 42,000 | 2.3 |
| Italy | 38,102 | 2.2 |
| Spain | 27,000 | 1.6 |
| Peru | 24,310 | 1.4 |
| Tunisia | 23,421 | 1.4 |
| Others | 180,000 | 10.3 |
| | 1,741,000 | 100.0 |

In this list Russia, United Kingdom, and Poland produced much that is credited to "others," but figures were not available because of war.




*World Lead Production in* 1939.

## *The World's Zinc*

As a separate metal zinc is relatively a newcomer in world use. Although it was known long ago that zinc ore smelted with copper produced brass, as a metal it has been used for less than two centuries. Zinc does not lend itself to ready production in the furnace, as do iron, copper, and lead. Its low boiling point requires a different method. It was first produced by reducing oxidized zinc ores in a retort and cooling the vaporized metal. Not until about the time of World War I were electrolytic methods developed that

proved satisfactory. These methods were used to produce about one fifth of our zinc in 1939.

In world production for 1939 we find the United States in leading place, as it was for steel, copper and lead. We produced 26% of the worlds total smelter production, 460,154 metric tons out of a total of 1,635,000.

This production expressed in short tons, the units we use in this country, was 507,236 tons. Of this, 491,058 tons was from domestic ores and 16,178 tons was from imported ores.

In addition to this we produced 189,640 short tons of secondary zinc from scrap.

Excepting for World War I and the boom years to 1928 our exports and imports of zinc in this century have nearly balanced. From 1914 to 1928 our exports exceeded imports by an average of about 70,000 tons per year, somewhat over a million tons total. It is probable that since 1880 we may have exported 1.5 million tons, net, above imports. Our total production of new zinc from domestic ores in that 62 year period was 17,457,000 short tons. This leaves us about 16 million tons that we have used as metal in 62 years.

Boys, we are ready for your next chart.

Boys: Here is the one with the United States uses of zinc.

TABLE XII
United States Uses of Zinc Metal in 1939
(Short tons)

| | | |
|---|---|---|
| Galvanizing | | |
| Sheets | 147,500 | 23.5% |
| Tubes | 43,300 | 6.9 |
| Wire | 33,000 | 5.3 |
| Wire cloth | 7,700 | 1.1 |
| Shapes, hardware, etc | 43,500 | 7.0 |
| Total galvanizing | 275,000 | 43.8 |
| Brass making | 175,000 | 28.0 |
| Rolled zinc | 62,000 | 9.9 |
| Die castings | 84,000 | 13.5 |
| Other uses | 30,000 | 4.8 |
| | 626,000 | 100.0% |

In "other uses" for zinc metal is included 17,169 tons of metal used to make zinc pigments and salts. With this metal we used enough ore and scrap so that the zinc pigments and salts made contained 133,967 tons of zinc, of which the difference, 116,788 tons, is not in the consumption given in the table.

The detailed uses of these materials would be more than anyone could name, varying from watch wheels and fruit jar tops, to automobiles and ammunition. It would be an interesing game to see who could make the longest list of articles in an automobile in which zinc is a constituent.

It is of great importance from the viewpoint of future supplies that so much zinc goes into uses from which none is ever recovered. In the greatest use, galvanizing, zinc is wholly lost with a single use. All zinc pigments used on structures are lost forever. Much of that used in brass is lost. While scrap brass is recovered the zinc is lost if the scrap is used for the recovery of the more valuable copper. If the brass can be used by remelting the zinc is saved. Of the scrap zinc recovered, 189,640 tons, only 45,100 tons was from old scrap. The remainder was from new scrap made in the processes of manufacture of zinc containing articles.

So when we come to consider how much zinc we may have left in use from the 16 million tons we have used as metal since 1880, we find quite a different story from that of lead, copper and iron. I am convinced that it would be highly optimistic to state that we have 5 million tons of zinc in use as metal or alloys. Probably more than three quarters of our production since 1880 is irrevocably lost. That is equal to our total production in 52 years from 1880 to 1932.

From this general picture it is not strange that shortages of zinc to meet war needs were foreseen before we were actually in the war. The government took steps both to restrict uses and to develop new sources of supply. Production was stimulated by a premium of 2¾ cents per pound for all zinc above the quota of the individual producer.

All this resulted in a supply that balanced war demand until mid-1942. The War Production Board stated then that "the United States faces the second year of war with uncertainty as to the adequacy of its future zinc supply."

### *World Sources*

For the world picture of zinc sources it is necessary to give both the zinc in ore produced and also the zinc smelted. Belgium, France, United Kingdom, Japan and Norway produced little ore but smelted a large amount of imported

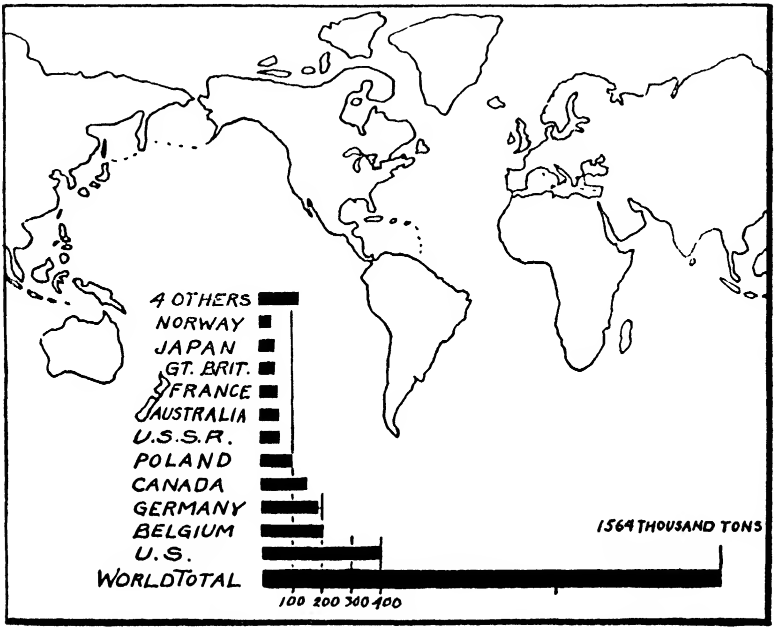
TABLE XIII
World Zinc Production in 1938
(In thousands of metric tons)

| | *Ore as Metal Content* | *Smelter Product* | |
|---|---|---|---|
| | | *Tons* | *Percentage* |
| United States | 468.7 | 404.9 | 25.8 |
| Australia | 223.3 | 70.9 | 4.5 |
| Germany | 203.0 | 194.4 | 12.5 |
| Canada | 173.0 | 156.0 | 10.0 |
| Mexico | 172.2 | | |
| Italy | 76.0 | | |
| U.S.S.R. | 71.0 | 71.0 | 4.5 |
| Poland | 70.1 | 108.1 | 6.9 |
| Newfoundland | 66.9 | | |
| Burma | 55.8 | | |
| Belgium | ...... | 210.3 | 13.4 |
| France | ...... | 61.0 | 3.9 |
| United Kingdom | ...... | 55.9 | 3.6 |
| Japan | ...... | 50.8 | 3.3 |
| Norway | ...... | 45.7 | 2.9 |
| Others | 289.4 | 135.7 | 8.7 |
| | 1,869.4 | 1564.7 | 100.0 |

ore. Germany exported some of its ore to Poland and Belgium to be smelted. When these two countries were taken over by Germany it became self sufficient in zinc.

Now can we have your chart on world zinc production?

Boys: In this one we have not shown tons of ore but tons of metallic zinc in the ore.




*World Zinc Production in* 1938.

Mr. Hotchkiss: Thank you, boys. You are getting to be expert chart makers.

The difference between zinc in ore and zinc in smelter production is accounted for partly by the use of ore directly in pigment manufacture and partly by the accumulation of ore stocks as war preparation.

Of the listed ore producers, omitting "others," the British Empire total amounted to 28%. Adding the other Allies,

again omitting "others," gives the Allied total of 66% of the metal in ore. Of the smelter production the British Empire had 18%. Adding the other allies gives the total of 45%.

Of the metal in ore produced the Axis powers together with occupied countries had 19%. Of the smelter production they had a larger proportion, 43%. So they were as well supplied with smelter capacity as were the Allies.

War needs caused a great expansion of our United States production of metallic zinc. In 1939 it was 557 thousand short tons from domestic, and foreign ores, and metallic zinc recovered from scrap. In 1940 it was 724 thousand tons. It was estimated at 880 to 890 thousand tons for 1941, and at 956 thousand for 1942.

Zinc prices averaged 5.12 cents per pound in 1939 and 6.34 cents in 1940. At these prices our zinc metal was worth a total of $57 million in 1939 and $92 million in 1940. The $57 million in '39 compares with $2,386 million for steel, $253 million for copper, and $67 million for lead.

### *The World's Aluminum*

In aluminum we have the most important of the new metals. Production began in the United States in 1893 with about 100 short tons. The rest of the world quickly took up the production of this metal and in 1895 when we produced 300 tons, other countries produced 700 tons. In 1900 our production reached 2600 and the rest of the world produced 4400 tons. In 1920 we produced 69,000 tons and others produced 71,800 tons. In 1940 our production had grown to 206,300 tons and that of other countries to 678,800 tons, all of primary aluminum. For most of the last ten years before the war Germany has been the leading producer.

The United States is the leading producer of steel, copper, lead and zinc, but in aluminum the leadership has passed out

of our hands, despite the fact that we were the first to produce the metal commercially.

The ore of aluminum is an aluminum oxide called bauxite, from the name of the province in France where it occurs in abundance. While aluminum is the most abundant metal in the rocks of the earths surface it occurs mostly as the silicate which is more difficult and more expensive to reduce to the metal than is the oxide.

Like zinc, aluminum ores cannot be reduced to metal by ordinary furnace methods. The chemically purified oxide is dissolved in molten cryolite and electrolytically deposited from the molten solution.

Our domestic ore has come very largely from Arkansas, with minor amounts and lower grade ores from Georgia, Alabama, and Tennessee. These sources are not sufficient for our needs so we import much more ore than we get from domestic sources. Our chief foreign source is Dutch Guiana, Surinam.

Bauxite is used in large quantities for other purposes in addition to making the metal. Of the 312 thousand tons we shipped from United States mines in 1939 only 161 thousand tons were used to make metal; 81 thousand tons were used to make aluminum chemical salts, mostly aluminum sulphate; 55 thousand tons were used to make abrasives, such as carborundum; and 14 thousand tons were used in petroleum refining, and other industries.

The various uses we make of aluminum metal depend chiefly on its lightness, its good electrical conductivity, and its capacity for making light, strong alloys. In 1940 the chief uses by industry were for transportation equipment (air, land, and water) 40%; foundry and metal working, 23%; machinery and electrical appliances, 9%; cooking utensils, 6%; electrical conductors, buildings, and chemicals, 5% each; ferrous and nonferrous metallurgy, 4%; food and beverage industries, 2%; and others, 1%.

The use for transportation was much greater than normal because of the war demand for planes. There were 12,636 planes built in the United States in 1940, 5888 military and 6748 commercial. In 1939 there were 2141 military and 3715 commercial aircraft built, a total of 5856. The monthly average in 1939 was 178 planes, in 1940 490 planes, in March '41 it was about 1100 and was expected to be at the rate of 2000 planes monthly at the end of '41. Before 1943 was ended the monthly rate reached nearly 9000 planes.

The United States production of primary aluminum in 1939 was 163,500 short tons. We imported 9,300 tons and exported 36,600 tons, leaving net for our own use 136,200 tons. In addition we recovered 50,000 tons of metal from scrap.

The war effect on the next few years produced a tremendous effort to increase production. The War Production Board announced in late '42 that before the end of 1943 the United States would have a total yearly supply of about 1,500,000 tons. This is nearly 10 times our production in 1939. The planes this vast tonnage produced have, without question, made possible the invasions in Italy, Normandy, and south France, and are saving the lives of uncountable thousands of our soldiers by the complete dominance of the air which they make possible.

The world situation in aluminum production is somewhat like that of zinc in that there are many producers of bauxite who make no metal, and many producers of metal who mine little or no ore. It is again the case of the ore being cheaper to transport to the coal, than it is to transport the coal to the ore. In this case it isn't coal so much as it is cheap electric power, for all the metal is produced electrolytically, and so abundance of cheap power is a primary requisite.

Now you boys may give us your chart of world aluminum production.

Dick: In just a moment. Here it is.

TABLE XIV

1939 World Production of Aluminum Ore and Metal

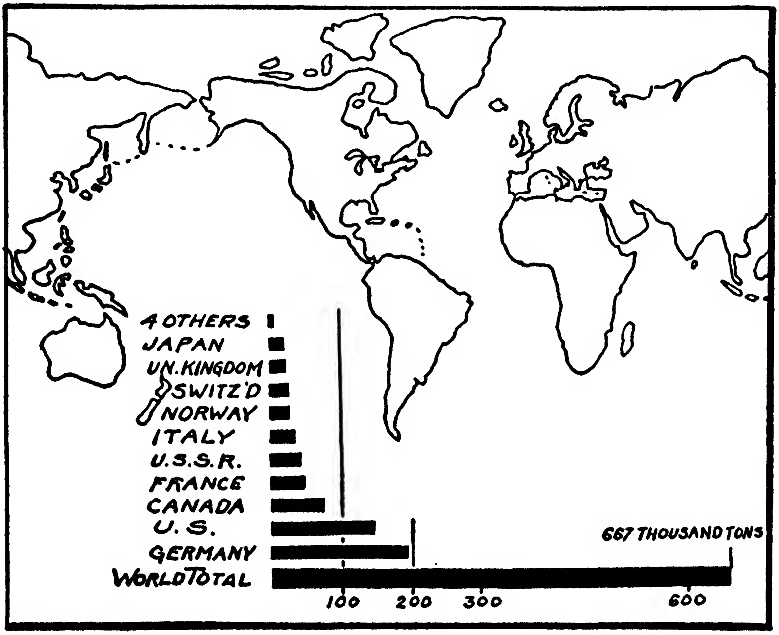
(In thousands of metric tons)

| | *Metal* | % | *Ore* | % |
|---|---|---|---|---|
| Germany | 200 | 30.0 | 20 | 0.5 |
| United States | 148 | 22.3 | 381 | 8.8 |
| Canada | 75 | 11.3 | | |
| France | 50 | 7.5 | 800 | 18.3 |
| Dutch Guiana | ... | ..... | 512 | 11.9 |
| Hungary | 2 | 0.3 | 485 | 11.3 |
| British Guiana | ... | .. .. | 484 | 11.3 |
| U.S.S.R | 45 | 6.7 | 270 | 6.8 |
| Italy | 34 | 5.1 | 484 | 11.3 |
| Jugoslavia | 2 | 0.3 | 319 | 7.4 |
| Netherlands Indies | . . | ..... | 231 | 5.4 |
| Greece | ... | ..... | 187 | 4.3 |
| Malay States | ... | ..... | 94 | 2.2 |
| Brazil | ... | ..... | 18 | 0.4 |
| Rumania | ... | ..... | 10 | 0.2 |
| Norway | 31 | 4.6 | | |
| Switzerland | 28 | 4.2 | | |
| United Kingdom | 25 | 3.7 | | |
| Japan | 23 | 3.4 | | |
| Others | 4 | .6 | 11 | 0.2 |
| | 667 | 100.0 | 4306 | 100.0 |

With the exception of the United States, France, Russia, and Italy no important producer of metal produced an appreciable amount of bauxite from which to make it.

The average per pound price of aluminum in 1939 was 19.75 cents. At this price our primary and secondary metal production had a total value of $84,350,000. The expansion due to war needs caused a reduction in price to 17 cents at the end of 1940. The producers stated that the larger production lowered cost, and that they were passing this saving on to the government in accord with their policy of sharing benefits of lowered cost with the public.

Our 1939 value of aluminum production, $84 million, compares with $2,386 million for steel, $253 million for copper, $67 million for lead, and $57 million for zinc.




*World Aluminum Production in* 1939.

## *The World's Magnesium*

More recent in its commercial debut than aluminum, magnesium has not yet found all the best ways it can be used. Of this metal, as well as aluminum, Germany is the chief producer.

In 1939 there were 8 countries producing magnesium. The total production was 32,800 metric tons, of which Germany produced a little over half, 16,500 tons, the United Kingdom was second with 5000 tons, and the United States a close third with 4,831 tons. Other countries producing

were France 2500 tons, with Russia, Japan, Italy, and Switzerland following.

The first production of magnesium in the United States was from salt brine residues in Michigan by the Dow Chemical Co. who were the only producers until war needs demanded more of the metal. The Dow Co. set up a large plant in Texas to use sea water as a source. Other plants were built to use dolomite and to use magnesite, both deriving metal from magnesium carbonate. Dolomite is a mixture of lime and magnesium carbonates, while pure magnesite is magnesium carbonate only, and therefore a richer source. Dolomite is a common rock and abundantly and widely distributed over the country, while magnesite is relatively scarce.

As processes were developed and perfected the cost was lowered. In 1918, a peak production year for the early stages, the 142 tons brought a price of $1.81 per pound. In 1927 the price had gone down to $.68, and in 1930 the 230 tons produced sold for 48 cents per pound. In 1934 production for the first time passed a thousand tons with a big leap to 2125 tons, which sold at 28¢ per pound. Production stayed about the same until 1940 when war needs increased it to 6262 tons at 27 cents a pound. A press release by the War Production Board in May 1944 stated that, for the first quarter year, production was over 60,000 tons. The production of magnesium is ample for the duration of the war.

So this new metal is rapidly finding useful jobs to perform to aid in that remarkable development that is sometimes called the American way of life.

## *The World's Tin*

In tin we have an ancient metal, traded in by the Phoenicians, of which the United States produces an insignificant amount, rarely as much as 100 tons a year. United States

production is *usually less* than one tenth of one per cent of what we import. We are the largest consumer of tin, normally using $\frac{1}{3}$ to $\frac{1}{2}$ the worlds production. We use about 2 to 3 times as much as the United Kingdom, the second largest user.

In 1939 we used 70 thousand tons of the world's 181 thousand tons of metal. Since 80% of our tin in 1939 came from southeastern Asia the taking of this region by Japan cut our supply grievously. Strenuous efforts were made to increase our supply before it was too late. The War Production Board stated that we imported 195 thousand tons of tin in 1941, nearly three times our 1939 imports. As they expressed it, "1942 was a year of learning how to do without tin."

Searches for tin ore in the United States were pushed by the Bureau of Mines and the Geological Survey, but without material success. In other countries supplying the Allies, chiefly Bolivia and Nigeria, production was stimulated as greatly as might be. A tin smelter was built by the government in Texas so that Bolivian ores would not have to make two, costly, time consuming and dangerous trips across the Atlantic before reaching us.

But with all that was done tin was critically short of supplying our needs.

We are ready for the chart showing uses of tin in the United States.

Bob: Here it is. Just think of the number of tin cans 23,000 tons of tin would make. There must be some truth in that old joke about "can-opener" cooks.

Mr. Hotchkiss: In 1938, a fairly normal year we used tin for the purposes shown in Table XV.

To make our war time tin go farther we expanded the use of a process of making tin plate by electrolytic deposition of the tin, rather than by dipping. By this method a satisfactory tin plate could be made with one third the tin

necessary in the dipping process. At the beginning of 1942 it was estimated that this would save 20,000 tons of tin in that year. Silver was used to replace some of the tin in solder and bearings, and containers of other materials were used in place of tin for many purposes.

TABLE XV

United States Uses of Tin in 1938



| | *Tons of 2000 lbs.* | % |
|---|---|---|
| Tin plate | 23,545 | 40.3 |
| Solder | 12,798 | 22.0 |
| Babbit | 4,157 | 7.2 |
| Bronze | 3,932 | 6.7 |
| Collapsible tubes | 3,427 | 5.9 |
| Tin oxide and chemicals | 2,067 | 3.6 |
| Foil | 1,773 | 3.0 |
| Type metal | 1,112 | 1.9 |
| Terneplate | 1,007 | 1.7 |
| Others | 4,457 | 7.7 |
| | 58,275 | 100.0 |

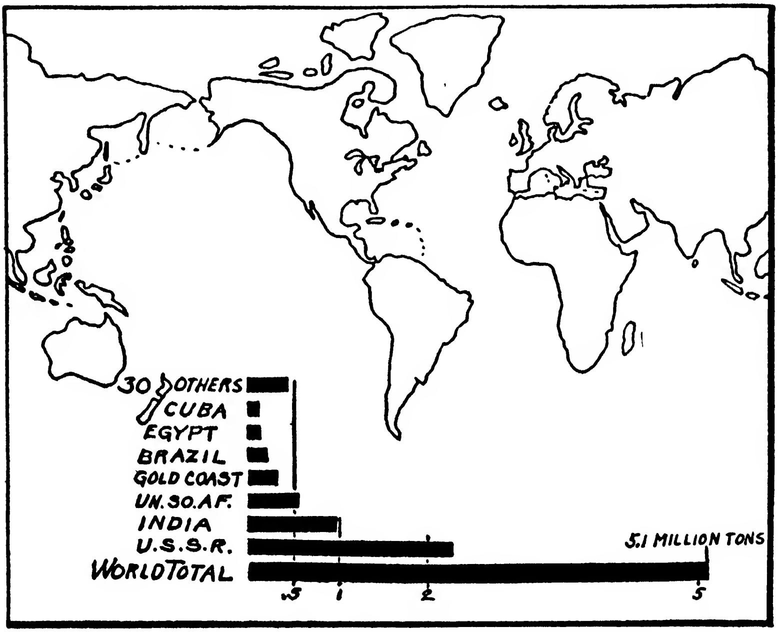
## *The World's Manganese*

Manganese is another metal which the United States possesses in gravely insufficient quantities. We must have about 14 pounds of it for every ton of steel we make. No substitute has yet been found for this purpose. Without it the quality of our steel would be gravely inferior instead of equalling the world's best. The manganese acts as a scavenger in the molten steel, taking harmful sulphur and oxygen with it into the slag. Manganese also has very important uses in steel alloys and for dry cell batteries but these uses require only a small part of the total.

In 1939 we imported our high grade manganese ore—the kind required for steel making—from the African Gold Coast 39%, from U.S.S.R. 22%, from Cuba 17%, from

India 14%, and from Brazil 7%. Our domestic production was less than one twentieth of our needs—only 30 thousand tons.

Our imports in 1939, for consumption, were 627 thousand tons with a value of 8.5 million dollars. Ninety million




*World Manganese Ore Production in* 1938.

tons of steel, which we have produced later in a single war year, demands over 1.25 million tons of high grade manganese ore.

This shortage of manganese caused active measures to be taken by the government; 1) to stimulate domestic production, 2) to increase imports, and 3) to build up a stock pile of reserves. All these steps met with some success. In 1940 our domestic production was 40,000 tons, and we imported 1,294,000 tons. A new important source of

imports was added, South Africa. By the end of 1942 a stockpile sufficient for two years needs had been accumulated.

The worlds production of manganese ore in 1938, the latest statistics available, came from six chief producers, the greatest of which was U.S.S.R. with nearly half the total.

Now you boys may hang up your chart on manganese ore production.

Dick: Here it is.

TABLE XVI

1938 World Manganese Ore Production

| | *Thousand Metric Tons* | % |
|---|---|---|
| U.S.S.R | 2,273 | 44.5 |
| India | 983 | 19.3 |
| Union of South Africa | 552 | 10.8 |
| Gold Coast | 329 | 6.4 |
| Brazil | 222 | 4.4 |
| Egypt | 153 | 3.0 |
| Cuba | 124 | 2.4 |
| Others | 471 | 9.2 |
| | 5,108 | 100.0 |

The total production in Europe in 1938 that would be tributary to Germany in 1944 amounted to about 150,000 tons. With this, plus whatever expansion of local production was attained, plus what undoubtedly was taken from Russian mines while the Ukraine was occupied, plus their pre-war stockpile, Germany has kept steel production supplied fairly well thus far. Now that the Germans have been driven away from Russian sources, and supplies from Rumania and Italy have been cut off they can continue their steel making only to the degree and for the time their scant new supply of manganese and their remaining stockpile of ore will permit.

Mr. Banker: How much better off we would have been if

we had had large stockpiles of manganese ore, tin and other minerals when the war began. Think of the worry and trouble and expense it would have saved, and the assurance it would have given.

Mr. Hotchkiss: You bring up a matter that I believe is vital in our post-war policy, Mr. Banker, and I hope to consider it later at some length.

*The World's Nickel*

Nickel is a third metal which the United States lacks. We are fortunate in that our friendly neighbor and ally, Canada, is the worlds chief source of this invaluable material. The 1939 United States production was 394 tons, all of which was a byproduct of copper refining. We imported about 65 thousand tons and exported a little more than 10 thousand tons. Our imports cost us 35 cents per pound or $700 per ton, a total for our imports of $45.5 million. This compares with $253 million for copper, $84 million for aluminum, $67 million for lead and $57 million for zinc.

We use nickel most largely in alloy steels, where it contributes toughness and resistance to corrosion. Other peace uses are in monel metal (a corrosion resistant copper-nickel alloy), coinage, resistance heating units in electric stoves and other heating purposes, and for plating articles to prevent their corrosion. Nickel steel is used in armor, and in guns and gun carriages.

The 1938 world's production of nickel, stated as metal content of ore, was 115.5 thousand metric tons. Of this Canada produced 95.5 thousand, New Caledonia 11.7 thousand, U.S.S.R. 2.5 thousand, Norway 1.2 thousand and Greece 1.2 thousand. Canada made 83% of the worlds total and we took 57%. In addition to those named, 13 countries produced less than 1000 tons each to make a total of 3,248 tons.

The war needs for nickel required restriction of use and

stimulation of production. The War Production Board estimated the United States essential requirements in 1943 as 5 times those of 1938. A large low grade nickel-bearing iron ore in Cuba was developed, through the aid of government money, to add to our nickel supply. A large deposit in Brazil, which is far from transportation, was investigated. The major solution of the need was found in expanding the Canadian output.

### *Other Alloying Metals*

In this list, in addition to manganese and nickel which we have discussed, we find chromium, molybdenum, tungsten and vanadium among the more important. Among those of lesser quantity and importance we find cobalt, beryllium, tantalum and zirconium.

Except cobalt these last are used in pounds rather than tons and while they have minor importance, they can only be mentioned here. Cobalt is not produced in the United States except a few tons as a byproduct. About 6000 metric tons of metal content in ore, it is estimated, were produced in the world in 1939. More than half of it came from Northern Rhodesia. It is used in the metal form in high grade steels for metal cutting, in magnet steels, also for electro plating and as a catalyst. Cobalt oxide is used largely in the ceramic industry as a color agent.

*Chromite*, the oxide ore of the metal chromium, is a fourth important metal resource of which we have an insufficient supply in the United States. In 1939 we produced 3,600 long tons and imported 317,500 long tons of crude ore. This 317 thousand tons contained 134,900 tons of chromic oxide. Of this oxide 55,000 tons came from Southern Rhodesia and Union of S. Africa, 29,000 tons from the Philippines, 22,000 from Cuba, about 8,000 tons each from India and Turkey, and 7600 tons from New Caledonia. We drew from the four quarters of the globe. No single producing country

produced as much chromite as we imported. Eleven countries produced over 40 thousand tons each, totalling 867,000 in 1938. Nine others brought the total to 20 countries producing 1,125,000 tons of the crude ore.

Chromite has three principal uses, for alloying with steel, as a refractory, and for chemical products. The steel industry, in 1938, consumed three quarters of the supply for two purposes, refractory use and alloy use. For alloy use the best ores with the lowest iron and the highest chromium content are required. Refractory and chemical uses can use lower grade ores. The chemical products are used chiefly in the dyeing, tanning and pigment industries, and as chromic acid in electroplating.

With these uses it is evident that war needs demanded a great increase in the supply. The War Production Board stated that for 1943 about 3 times the 1939 supply was needed. Vigorous government exploration found supplies of low grade ores suitable for refractory and chemical needs.

The chromic oxide content of 1939 imports cost us 14 cents per pound.

*Molybdenum* is the single one of the important alloying metals of which the United States has a practical monopoly, with over 90% of the worlds production in 1939, 30,324,000 pounds out of 33,000,000 pounds total. The rest come mainly from Mexico and Norway.

Molybdenum is used in alloy steels needed by the automotive, airplane and oil industries. In the early war stages molybdenum was substituted, in many uses, for scarcer alloy metals such as chromium, tungsten and nickel. Use as a substitute ate into the supply so greatly that it was necessary to increase production, and to find new ore bodies. The metal content of the ore was worth about 75¢ per pound in 1939.

*Tungsten* is an important metal for lamp filaments and for alloy steels used for tool steels and armor plate. About 90%

is used in tool steels. United States production had increased before the war to nearly 39 hundred tons of concentrates. Its great use in war caused this to double in 1940 and redouble in 1941. Intense activity in exploring for new deposits by the Bureau of Mines and the Geological Survey resulted in development of new domestic sources. Production elsewhere in the western hemisphere was stimulated and imports increased so a stock pile was built up as protection for war needs.

World production of tungsten in 1938 was 35.8 thousand metric tons of ore containing 60% of tungsten oxide. Of this China produced 37.5%, Burma, 17.6%, and Portugal and United States followed with 7.8% each. Chosen, Bolivia, Argentina and Australia produced most of the remainder. We imported, in 1938, ore and concentrates totalling 81 short tons of metal content at a cost for the metal of 85 cents a pound. In 1939 the metal content of our imports was 743 tons worth $997,971 or at the rate of 67 cents a pound.

*Vanadium* is a metal which we have in the United States in some abundance, but we import approximately as much as we produce. The world production of the metal in ores in 1938 was equivalent to 2669 metric tons. Peru produced 31% of this, United States 27.4%, S. W. Africa 20.8%, Northern Rhodesia 14% and Mexico 6.8%.

The principal use is for alloy steel. The alloy steel is used chiefly for highspeed cutting tools and for armor plate. Vanadium is also used in glass, ceramic and color industries.

In 1939 we imported ores containing 2,132,548 pounds of the metal, valued at $991,511, or about 47 cents per pound.

Vanadium is also recovered as a byproduct, from some blast furnace slags, from refining of bauxite, and, of all strange sources, from soot from stacks of vessels burning Mexican and Venezuelan oil.

War needs increased demand greatly, as for all other

alloying metals. Government prospecting developed large new sources and supply is believed to have been adequate.

### *The World's Antimony*

Antimony is another of the metals the United States produces in too small amounts to supply its needs. In 1938 we produced ore carrying 650 short tons of metal. We recovered 8,500 tons of secondary antimony, mostly from old scrap. We imported 9,897 tons—about 28% of the worlds total production of 35,600 short tons.

Antimony is used chiefly for the qualities it imparts to lead when alloyed with it. The two largest consumers are storage battery plates and cable covering, with bearing metal and type metal taking lesser amounts. It is used also in chemicals and for military purposes, for primers and pyrotechnics.

Of the world production in 1938 Bolivia, China and Mexico produced approximately one quarter each. Twenty-seven countries produced antimony.

Prices of antimony vary between 11 and 16 cents per pound.

### *The World's Mercury*

This metal is produced in the United States in ordinary times in quantities to meet about half our needs. Only our richer ores can compete with foreign producers in peace times. When war cut off foreign supplies and at the same time multiplied our needs the consequent price increase permitted production from lower grade ores and so increased our production. Exploration and production, stimulated by the government, helped to meet the greater demands.

Mercury is sold in units of "flasks," containers holding 76 pounds of metal. United States production in 1936 to '38 averaged about 17,000 flasks. Our imports were slightly larger until war loomed in Europe. Our imports for consumption in 39 fell to 2362 flasks and in 1940 to 171 flasks.

Our production made a small increase in 1939 and doubled in 1940, when it totalled 37,777 flasks. In 1941 we produced 44,921 flasks. Later production figures are not given out but almost surely show increases. Mexican production was greatly stimulated by the increased price.

The world production in 1938 was 148 thousand flasks, about eight times that of the United States. Italy produced 66,800 flasks, Spain 42,100, United States 18,000, U.S.S.R. 8,700, Mexico 8,500 and other countries 6,400 flasks.

The Almaden mine in Spain is the most famous source of mercury. Owned successively by Romans, Moors, and Spaniards it has operated for 2000 years, probably the only mine of any kind with such a history. The New Almaden mercury mine in California has operated for nearly a hundred years.

Mercury has a wide variety of uses. Greatest is in drugs and chemicals, which take nearly half the peace time supply. Of these calomel and corrosive sublimate are commonly known items. The fulminate, used for detonating explosives, uses in peacetime about a quarter. In war this of course is much greater. One little known use is as a liquid in place of water in special boilers in large power plants. Two large installations of mercury boilers were in use before this last war. Mercury is used for a great variety of scientific purposes, from the familiar thermometer and barometer to the mercury lamp and scientific equipment of many kinds. It is used in the manufacture of felt, as pigment, in the manufacture of caustic soda and acetic acid, and in dental amalgam. These do not tell the full story. It is an exceedingly versatile slave doing many tasks that no other is able to perform.

### *The Precious Metals*

Gold, silver and the platinum metals are produced in the United States, the first two in large values from large deposits,

the last in quantities too small to meet our needs. The production of these metals is stated in ounces. The price of gold in 1938 was $35 per ounce and silver was 64.6 cents per ounce, both set by government. The price of platinum is determined by a free market and has varied widely from double to half the price per ounce of gold. In 1939 it varied from $26 to $45 per ounce.

The United States production in 1938 was of gold 4.2 million ounces, of silver 61.7 million ounces, and of platinum 48.3 *thousand* ounces.

World production of gold in 1938 was from South Africa 12.2 million ounces, U.S.S.R. 5.2 million, Canada 4.7 million, United States 4.2 million, Australia 1.6, others 9.7 million ounces. The British Empire produced half the total.

World production of silver in 1938 was from Mexico 81.0 million ounces, United States 61.7 million, Canada 22.2 million, Peru 20.6 million, others 82.2 million. The western hemisphere dominates the silver production of the world.

World production of platinum in 1938 totalled 537 thousand ounces, a very small fraction of the gold or silver production. This production came from five large producers —Canada 292.2 thousand ounces, U.S.S.R. 100.0 thousand ounces, South Africa 58.7 thousand, United States 48.3 thousand, Colombia 34.5 thousand, and from others 3.3 thousand ounces. Canada's great production comes almost wholly from the refining of the nickel and copper ores of Sudbury.

Platinum finds its use chiefly in jewelry with lesser amounts in the chemical, electrical, and dental industries. The industrial uses are of great importance and no satisfactory substitutes are available for many of them. There has been no serious shortage due to war demands as more than half the worlds production is from Canada.

Gold finds its greatest use as a basis for paper currency. In addition to its uses in jewelry, in dentistry and its decora-

tive uses as goldleaf, gold finds industrial application in the chemical industry where its resistance to corrosion is of value.

Silver is used widely in coinage and as a basis for paper currency. Its industrial uses are many and varied. During the war, when copper was short, government silver was loaned to replace bus bars of copper in electric generating plants. Its resistance to corrosion has given it wide use in table wear and jewelry, and in plated articles. It finds wide use in chemical industry, in surgery, in dentistry, in solders, in bearing metal alloys, and in the electrical manufacturing industry

*Summary*

This completes the list of metals that have most importance. There are others but the amounts we use are very small. While some of them serve special limited purposes in most useful fashion, it would take too much time to discuss them all, and it would be even more technical than I have had to be in discussing those we have named.

Mr. Banker: I know little about metals but I have been very much interested in the picture you have given of their use. I am wondering if you can't give us some picture of the amounts of these metals that each of us has to serve him out of the usual yearly production.

Mr. Hotchkiss: It will be quite easy to divide the total production of each metal by the number of people in the U. S. and give you the number of tons or pounds that there would be for each of us. I think it would be perhaps more interesting to consider *volume* of metal instead of the *weights* we use ordinarily. This wont seriously change the relations of the older metals iron, copper, and zinc, since they all weigh nearly the same per cubic foot. But for lead, the heaviest of the common metals, and for the light metals, aluminum and magnesium, it will give a quite different

relationship. We *buy* metals by weight but we *use* them in most cases for properties we measure by volume.

We use metals mostly on the basis of their mechanical properties, such as tensile strength, hardness, elasticity, and ductility, or because of their electrical or heat conducting properties. When weight enters into the use of metals it is in the matter of pounds required to give the strength needed. So for airplanes we use the light metals because we get the strength needed with a lesser weight of metal.

All these characteristics are measured by volume. Tensile strength is measured by the strength of a bar one square inch in cross-section. Electrical and heat conductivity are measured as that of one cubic centimeter. Hardness is measured by the volume displaced by a steel ball pressed into the metal by a given weight, or by the weight required on the ball to displace a uniform volume.

So on the basis of effective use there is much justification for considering the metals on the basis of volume.

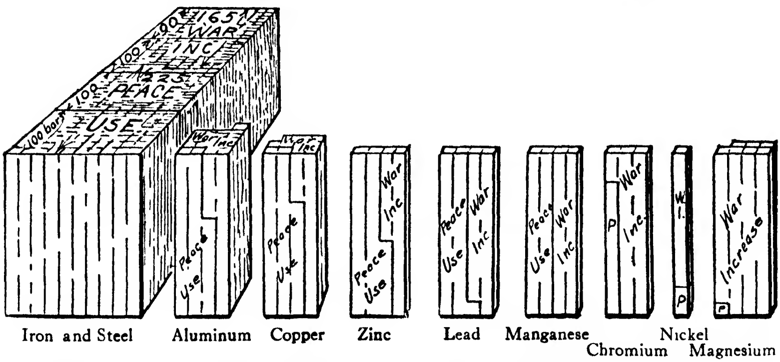
To give you these relationships I have reduced the share of the metal we use, that each would have if it were divided equally between the 135 million of us, to a rod one inch square. The length of the rods of the various metals gives their relative volumes. These computations are for the purpose of giving a general picture so no attempt has been made to attain handbook accuracy. They are based on the use of the metals, per capita, as shown in Table XVII.

If the average citizen had to use all these metals himself instead of having them used for him by all the complex manufacturing, transportation, power, agricultural, communication and other industries as he does now, he would have to buy yearly about 812 pounds of metal for every member of his family. This would be a good load for his automobile. Seven hundred and seventy pounds would be steel and forty two pounds of other metals, some of which he wouldnt recognize when he saw them. Nevertheless

they are all necessary to his welfare and happiness. If he bought these metals in 1939 in the form of one inch square

TABLE XVII

| *Metal* | *United States Consumption, 1938 or '39* | | *Consumption, War Years* | |
|---|---|---|---|---|
| | *Pounds per Capita* | *Length of 1 Sq. In. Rod* | *Pounds per Capita* | *Length of 1 Sq. In. Rod* |
| Iron | 770 | 225 ft. | 1340 | 390 ft. |
| Copper | 10 6 | 2 75 | 44 | 11 |
| Lead | 10.0 | 2.1 | 20 | 4 |
| Zinc | 7.6 | 2 45 | 14 | 4 to 5 |
| Manganese (as metal) | 6.3 | 2.0 | 12+ | 4 |
| Aluminum | 2.75 | 2.58 | 23 | 21 5 |
| Chromium (metal) | 2 5 | 0.82 | 10 | 2.5 |
| Tin | 1.04 | 0.33 | | |
| Nickel | 0.8 | 0.21 | 4 | 1 |
| Magnesium | 0 05 | 0 07 | 5 | 7 |
| Total | 811.64 | 238.31 ft. | 1472 | 346 ft. |




*Number of bars, twelve inches long and one inch square, of each metal used by or for each man, woman and child in the United States in* 1938 *or* 1939, "*Peace Use,*" *and the added number needed for war in* 1943, "*War Increase.*"

bars each a foot long, or a fraction, and set them up before him on a strong table, he would have 225 steel bars, 2.75

copper bars, 2.58 aluminum bars, 2.45 zinc bars, 2.1 lead bars which he might recognize. In addition he would have other bars he might not be able to identify without a label though he might be able to guess the tin and the nickel. He would have 2 bars of manganese, 0.82 of a bar of chromium, 0.33 of a bar of tin, 0.21 of a bar of nickel, and 0.07 of a bar of magnesium.

During the present World War years his steel bars would have increased in number from 225 to 390. His aluminum bars from 2.58 to 21.5, and his magnesium fraction of a bar, a little over three quarters of an inch long, to 7 full bars. In general, except for steel, he would have from two to 5 times as many bars of any one metal as he had in a normal peace time year. He would have a total of 346 bars instead of the peace time total of 238 bars.

Of gold, silver, and platinum that we produced (or used, in the case of platinum) the per capita amounts for 1939 were, gold .042 ounce, worth about $1.47, silver, .48 ounce worth 31 cents, and platinum about 2 thousandths of an ounce worth perhaps 5 cents. These figures suffice to show the relatively infinitessimal amounts of the precious metals. That .042 ounce of gold would be about a third the size of a dime, the .48 ounce of silver would be about the size of a half dollar, and the 2 thousandths of an ounce of platinum would be about the size of one of the pieces if a dime were cut into sixty parts, about a large sized pin head.

Mr. President: This has been a very interesting picture to us steel men. It would be very good if all our people, including those who haven't our special interest, could understand this situation. The tables and charts of production and use I want to have reproduced, so each of us can have a copy for reference. I hope you have no objection.

Mr. Hotchkiss: None at all. I am glad they have interested you enough so you want to keep them.

Mr. Superintendent: I hope you have an equally instructive set of charts and tables to show us when you take up coal and oil, and the other non-metals.

Mr. Hotchkiss: I have had Bob and Dick make the same kind of tables for these. We are ready to take these up in the next session.

# CHAPTER 5

# Sources and Production of Mineral Fuels and Other Non-metallics

THE mineral fuels, both in dollar value and in usefulness, outrank all other mineral resources. Those areas of the world in which coal is mined in large quantities are the great industrial districts, the homes of the greatest wealth, and the seats of the worlds strongest political powers. The utilization of the petroleum of the world may possibly change this in the future but so far it has served chiefly to accentuate the importance of the areas having plenty of coal.

The United States is blessed with a vast production of both coal and oil, and so, for some time in the future, is assured of the primacy which an *abundant* supply of these two resources entails. Russia is the only other great power having large production of both coal and oil. The other two great industrial nations, England and Germany have large coal production, but are obliged to import their oil, or as in the case of Germany, to manufacture it in part from coal at a greater cost.

These two mineral fuels, plus natural gas and water power, are the great sources of the energy we use in our industrial processes, and in heating our homes and places of business. Another source of energy used extensively in the United States is wood which heats many homes and fires many small steam boilers. The quantity of this we do not know as we know the coal and oil. Another unknown is "bootleg" coal mined and used or sold by people who do not own it. The quantity of this has been estimated to be as great as 4

million tons a year. But the energy in both wood and bootleg coal probably does not amount to more than 2 to 4 percent of the total so it can be neglected without seriously affecting the figures.

The energy we get from water power is a larger part of our total so it is fortunate that we have better statistics.

The U. S. Bureau of Mines has for many years been giving us records of the total energy production in the form of coal, petroleum, natural gas and water power. The unit of energy taken to serve as a common denominator between these energy sources is called the British thermal unit (B.t.u.). It is the heat energy required to raise the temperature of a pound of water one degree Fahrenheit. The average pound of bituminous coal has 13,100 of these energy units in it. A 2000 pound ton has 26,200,000 B.t.u. in it. The 400 million tons of bituminous coal we mine in a year has B.t.u. to the total of about 10,000,000,000,000,000. Such astronomical figures are too large for any of us, even in these days when we have learned to talk glibly of billions of dollars of debt. If we divide that 10 with fifteen zeros behind it by a thousand billion (one trillion) we have 10 thousand big units of energy each consisting of a trillion B.t.u. So the Bureau of Mines has wisely given us energy units in these terms so we dont have to strain our minds too greatly to get relationships.

In 1900 our energy production in the form of coal, oil, gas and water power totalled 8,000 of these trillion size units. We could express this as 8 quadrillion B.t.u. if we wanted to but who knows what a quadrillion is. So we'll stick to the 8,000 units.

Of this total the energy in coal was 88.9%. The energy in petroleum was 4.8%, that in gas 3.2%. This makes a total of 96.9% from mineral sources, and leaves 3.1% that we got from water power. These made a grand total of energy of 8,000 units.

In 1940 the grand total of energy we produced was 25,368 units—an increase to 3.2 times what we produced in 1900.

But the distribution was decidedly different. While the energy in the coal we produced was double what it was in 1900 it was only 52.2% of the total instead of the 88.9% it was in 1900. The energy in 1940 in petroleum increased to 29.7 times what it was in 1900 and was 33% of the 1940 grand total. The energy in 1940 production of natural gas was 11.3 times what it was in 1900 and made 11.3% of the energy total. The energy in water power produced in 1940 was 3.6 times what it was in 1900 and was 3.5% of the 1940 grand total.

These energy figures give the total available for our use from these natural resources. We do not use them with 100% efficiency, however, so we do not at present have this amount of energy to use. The efficiency of the use is not known. We know the best electric generating plants approximate 35% efficiency and that the average generating plant is about 16% efficient. General use of coal is probably approximately 5% efficient. Petroleum and natural gas may be used somewhat more efficiently in many cases. In automobile use of gasoline the efficiency probably averages between 5 and 10%. Since about half the natural gas is used in the oil fields for well drilling, for operating wells and pipe lines, and for burning to make carbon black, its efficiency must be very low on the average even though some industrial uses may be fairly high in efficiency. We will not be far wrong if we use 6% as the figure for what we actually get in the way of energy used.

If we assume that we used our fuels with 6% efficiency, out of the 25,368 trillion sized units available in 1940 we actually got 1,522. Even at this low efficiency we had the equivalent of 20 slaves working eight hours a day, 300 days a year, for every man, woman, and child in the United States.

In 40 years time this "slave equivalent" of our used mechanical energy has increased from 5 or 6 to 20 slaves for each of us.

If we could double the 6% efficiency we could increase the "slave equivalent" to 40 for each of us. We would then be using only one eighth of the energy in our production of coal, oil, gas, and water power and would still be losing seven eights of it, a loss which would leave plenty of leeway for diligent searchers for greater efficiency.

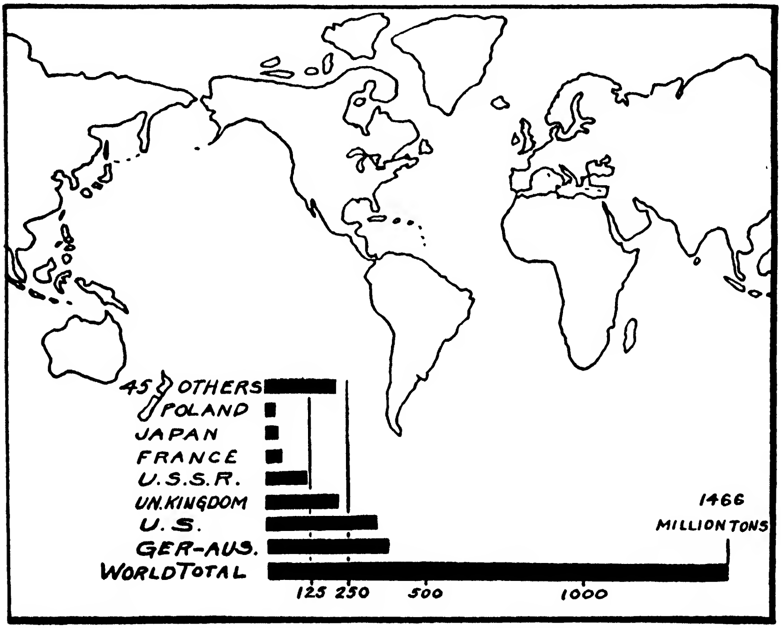
But to double our present low efficiency is not an easy task. It is not only an engineering problem. It is a scientific problem of the first magnitude in which new scientific facts in chemistry and physics, as well as engineering, will probably be a necessary background before we can hope for success. In our present wastefulness we haven't done so badly compared to mother nature, who wastes many thousands of acorns to produce one oak, an efficiency of less than 1 tenth of 1 percent if producing oaks is the only purpose of acorns.

With this introduction giving us a picture of the small efficiency with which we are now using them we can consider these mineral fuels and where the world's supplies come from.

### *The World's Coal*

Coal occurs as three recognized kinds, lignite, bituminous and anthracite. All three are vegetation of long geologic ages ago, which in favorable conditions had accumulated in beds thick enough to be of value to us today. This ancient vegetable matter has been changed by the compression and heat of deep burial under a load of later sediments. This compression and heat have caused the vegetation to alter chemically and physically. The long time they have acted has produced such marked change that we no longer recognize readily the original material. Water has been driven out of the vegetable matter. Decay has resulted in

breaking up the material and releasing part as gas and leaving the carbon, partly in the form of the uncombined element, the "fixed carbon," and partly still combined in forms that leave the coal as gas on heating—the "volatile matter." The process of alteration to coal as it progresses




*World Coal Production in* 1938.

gradually rids the material of the volatile matter and so increases the fixed carbon.

The three kinds of coal recognized can be looked at as various stages of the process of making coal from vegetable matter. Lignite is the earlier stage in which volatile matter is higher and fixed carbon lower than in the other two kinds. Bituminous coal is the intermediate stage, and anthracite is the later stage in which most of the volatile matter has

gone and the fixed carbon makes a greater part than in the other two kinds. Most of the coal produced in the world is the intermediate stage—bituminous. Lignite is much less desirable for ordinary use than the other two kinds and is relatively little used.

Germany is the only large producer of coal which used more lignite than coal in 1938, 172 thousand metric tons of coal and 195 thousand of lignite. Central Europe and the Balkan countries are the only coal countries of the world where lignite is an important factor in the supply. The total lignite was less than ⅛ of the total world production of coal in 1938.

Bob, will you and Dick show us your table on world coal and lignite?

Bob: All ready. I'm glad coal isn't one of the mineral resources we lack.

TABLE XVIII
1938 World Production of Coal and Lignite
(In thousands of metric tons)

| | | *% of Total* |
|---|---|---|
| Germany-Austria | 385,058 | 26.2 |
| United States | 358,013 | 24.5 |
| United Kingdom | 230,659 | 15.7 |
| U.S.S.R. | 132,888 | 9.1 |
| France | 47,555 | 3.3 |
| Japan | 43,500 | 3.0 |
| Poland | 38,114 | 2.6 |
| Others | 230,213 | 15.6 |
| | 1,466,000 | 100.0 |

Forty five countries make the production included in the table under "others," only four of which produce over one percent of the total each. The four produce 7.3%. The Allies produced, omitting "others," a total of 49.3% of the total in 1938, and the Axis powers 35.1%, with enough from conquered countries to make a total of 42%. So their coal

supply is nearly equal to the Allies, and nearly, if not quite ample for their needs.

The southern hemisphere produced little coal. It had less than 3% of the world's coal, oil, and water power production in 1938.

The United State coal production in 1939 was anthracite 51.5 million 2000 pound tons, bituminous 393 million, and lignite 3.0 million tons. The average prices received at the mine or breaker were $3.85 for anthracite, $1.85 for bituminous, and $1.14 for lignite.

Anthracite might be considered as two groups. 1) the sizes for domestic use which in 1939 averaged $4.64 per ton and was two thirds of the total tonnage, and 2) the steam sizes, a third of the product, which sold for an average of $2.25. Bituminous coal shipped to the consumer by rail in 1938 paid a freight charge of $2.23 per ton, on the average. The consumers average cost delivered was 55% freight. Of course this varies with the distance, short haul coal has a lower, and long haul a higher freight cost to the consumer. The total value of 1939 coal production was $920 million at the mines.

The production of coal in the United States is widely distributed. Twenty six states are listed as each producing more than 10,000 tons of bituminous coal and lignite in 1939. Of these 28 states only six produced less than a million tons each.

The great coal producing states lie in two areas, the eastern including Pennsylvania, Ohio, Maryland, West Virginia, Kentucky, Tennessee and Alabama, and the central, comprising Illinois, Western Kentucky, and Indiana. West of the Mississippi there are great coal fields, but the great industrial need is not there to demand great production. West of the Mississippi only five states produced more than 3 million tons each in 1939. Colorado led with 5.9 million, closely followed by Wyoming with 5.4 million. Utah

produced 3.3 million, Missouri 3.28 million, and Iowa 3.0 million. Eleven other western states produced a total of 14 million.

East of the Mississippi are the giant producers in 1939, led by Pennsylvania with 143.7 million tons of which 92.2 million were bituminous and 51.5 million were anthracite. West Virginia was second with 107.9 million tons. Then followed Illinois with 46 million, Kentucky with 42.8, Ohio with 19.6, Indiana with 16.6, Virginia with 13.2, Alabama with 12.0 million, Tennessee with 5.3 million, all in 2000 pound tons.

The uses of coal are so many that we must content ourselves with naming only the principal avenues of consumption.

Anthracite is largely a domestic luxury coal. Its cleanness and smokelessness are so desirable that consumers are willing to pay the greater cost. The small sizes, unsuited for domestic purposes, are largely used in steam plants.

Bituminous coal finds its greatest single use in manufacturing. There are no data on this directly, but after the great known uses are accounted for there was left 190 million tons which supplied manufacturing, domestic, and miscellaneous uses. Our consumption of bituminous coal in the United States in 1939 was reported as 378 million 2000 pound tons. Locomotive fuel requirements were 73.8 million tons, coke ovens took 63.5 million, electric utilities used 46.2 million, bunker coal for ships required 1.5 million and the mines used for their own needs 2.8 million. The three named big users, railroads, utilities, and coke ovens, used very nearly half the total, and manufacturing, domestic, and miscellaneous users took the rest.

Coke is a vital part of our industrial picture. Only certain kinds of coal can be used to make coke that is strong enough and otherwise suitable to serve in the blast furnace. Only a small part of Illinois and Indiana coal is suitable for coking. The coke for our great iron and steel industry

comes almost wholly from the eastern coal fields, stretching from Pennsylvania to Alabama. Of the 62 million tons of coal used to make byproduct coke only a little more than one million tons came from other states—Colorado, Utah, and Illinois in order of importance.

Coke is made by roasting coal in an oven to drive off the volatile matters and leave only the fixed carbon. Formerly it was made in "bee hive" ovens—so named from their shape—in which the gas and other volatiles were wasted. Now all but 3.5% is made in byproduct ovens, so called because the byproducts are largely saved. These byproducts make up about 30% of the coal charged into the ovens, the coke produced makes the other 70%—43 million tons in 1939. Of this total 31.8 million tons was used in iron and steel furnaces.

The byproducts in 1939 sold for $135 million, a very sizeable value that was largely allowed to go to waste prior to World War I, before byproduct ovens came into general use.

Mr. Manager: Hasn't the war increased the tonnage of "bee-hive" coke? I know we are using some at our furnaces, and before the war we only used byproduct coke.

Mr. Hotchkiss: The war increase in steel production has demanded more coke than the byproduct coke plants could supply, so many old bee-hive ovens were put back into use.

Boys, we are ready for your chart on the byproducts of coke making.

The byproduct ovens produced, per ton of coal charged, the following materials in 1939.

TABLE XIX

Coke and Byproducts per Ton of Coal

| | |
|---|---|
| Coke | 70.5% |
| Gas—thousands of cubic feet | 11.3 |
| Surplus sold | 7.08 |
| Tar—gallons | 9.06 |
| Ammonia and compounds, lbs | 22.33 |
| Light oil and naphthalene, gallons | 2.99 |

About one third of the gas produced is used to heat the ovens, and the surplus is sold or used about the works if needed for other industrial purposes.

The tar byproduct is the source of a host of the so-called "coal tar derivatives." Many books would be needed to discuss these, as they play a large part in chemical industry. Furthermore those books would have to be written by someone who knows more about them than I.

Modern explosives—picric acid and T. N.T.—are made from coal tar. For the present war the petroleum refineries have furnished a badly needed additional source of the toluene for T.N.T. Agents for denaturing alcohol are made from tar. Perhaps it is appropriate to mention next that tear gas also comes from tar. Antiseptics, and anesthetics are made from tar, and a host of other drugs, and disinfectants. All but one of these mentioned are war necessities. Coal tar is the source of many dyes, plastics, dry cleaning agents, and ingredients for soaps and polishes. Tar is used as anti-corrosive paint. It furnishes the creosote for preserving our railroad ties, telephone poles, and other wood uses. It is a valuable roofing material, and a most useful road binder. Electrodes for electric furnaces, motor fuel, perfumes, and many synthetic resins used for plastics acknowledge their coal tar ancestry.

Coal tar truly is a most versatile and valuable byproduct.

### *The World's Petroleum and Natural Gas*

Petroleum and its products are the worlds most vital war munition. Without them no nation can successfully carry on war with a nation that has an adequate supply. No air force and no tanks are possible without vast quantities available. No navy is modern or efficient that is not oil operated. No army supply system can function without oil driven transport. No large army can be fed or armed without trucks. No artillery can be effective without

tractor drawn guns, and oil produced explosives. If it had no supply of oil, or could not hope to capture it, no modern military power, no matter how great its manpower, would even think of war with a nation well provided with oil.

So it is fortunate for us in World War II that the United States produces more than half the worlds petroleum. Even with this overwhelming proportion greatly increased in the emergency, certain uses have had to be curtailed drastically in order to provide our military forces with an adequate supply.

The world petroleum production in 1939 was 2,077 million barrles, of which the United States produced 1,264 million, or 61%. In that year we also produced nearly 90% of the worlds natural gas. Our natural gas in 1939, measured by its heat energy content, was the equivalent of 35% of our petroleum production. Our high percentage of the worlds natural gas is probably due to the fact that other large oil producing areas waste gas as we formerly did, before there was industrial use developed for it. But we cannot boast too much about the efficiency of our use of natural gas. It had a sales value averaging, in 1939, 5 cents per thousand cubic feet at the wells. This price is not conducive to the economies we are forced to adopt with something expensive. The average price delivered to large consumers was 22.2 cents per thousand cubic feet.

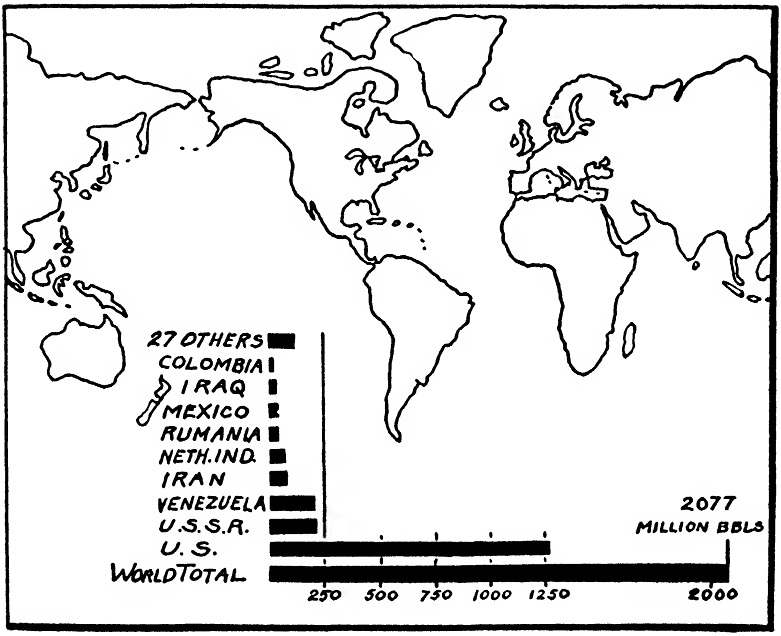
The production of natural gas in '39 was almost 2.5 million million cubic feet. This astronomical total is equal to 17 cubic miles. It is the same in volume as a mountain 3000 feet high with a circular base eleven miles in diameter.

Our petroleum production in '39 had a total value for crude, at the wells, of $1,294 million. Our natural gas had a value of $539.6 million at the wells. The natural gasoline squeezed out of the gas before it was sold was worth $94.3 million.

The total value of these three products in '39 was $1,957,-000,000, enough, almost, to pay one tenth of the money

raised by the government in the Sixth War Loan drive in December 1944.

This total is one and a half times the total value of all the gold, silver, iron ore, copper, lead, zinc, and all the other metals we produced that year. It is more than double the value of all the coal we produced in 1939. If we add




*World Petroleum Production in* 1939.

together the value of all the metals and all the coal produced in the United States in 1939 the value of our oil and gas would be almost equal, it would be 85% of it.

Stimulated by war demands, production in 1940 was increased to 1,352 million barrels of oil, and 2.7 million million cubic feet of natural gas. The total value of petroleum, natural gas, and natural gasoline production was $2,014,

000,000. In 1941 the total value of these three products was $2,278,000,000. In 1943 crude oil production was 1,503 million barrels.

Boys, will you show us your chart of world petroleum production?

Bob: We are ready with it. We also made a chart showing the production of the United States by states, which we will show you after the world chart.

Mr. Hotchkiss: The production of the various countries is given in the table.

TABLE XX

World Petroleum Production 1939

| | *Million of Barrels* | *Percentage of Total* |
|---|---|---|
| United States | 1,265 | 60.9 |
| U.S.S.R | 212 | 10.2 |
| Venezuela | 206 | 9.9 |
| Iran | 78 | 3.7 |
| Netherlands India | 62 | 3.0 |
| Rumania | 46 | 2.2 |
| Mexico | 43 | 2.1 |
| Iraq | 31 | 1.5 |
| Colombia | 22 | 1.1 |
| Others—all under 20 million | 112 | 5.4 |
| Total | 2,077 | 100.0 |

The production in the United States is well distributed. Twenty two states scattered over the country from the Alleghany Mountains to the Pacific produced oil. The chief producing states are shown in table XXI. It is interesting to compare the production of our leading states with that shown for various foreign countries in table XX. Both Texaş and California produce more than U.S.S.R. Oklahoma, Illinois and Louisiana production is exceeded only by U.S.S.R. and Venezuela. Six of our states exceeded Rumanian production in 1939. Since the air raids on the

Rumanian fields in 1944 its production has probably fallen below some of our other states.

TABLE XXI

United States Petroleum Production 1939

| | *Millions of Barrels* | *Percentage of U.S.* | *Percentage of World* |
|---|---|---|---|
| Texas | 485 | 38.4 | 23.4 |
| California | 224 | 17.7 | 10.8 |
| Oklahoma | 160 | 12.7 | 7.7 |
| Illinois | 94 | 7.4 | 4.5 |
| Louisiana | 94 | 7.4 | 4.5 |
| Kansas | 61 | 4.8 | 3.0 |
| New Mexico | 37 | 2.9 | 1.8 |
| Michigan | 23 | 1.8 | 1.1 |
| Wyoming | 21 | 1.7 | 1.0 |
| Arkansas | 21 | 1.7 | 1.0 |
| Pennsylvania | 17 | 1.3 | 0.8 |
| Others—all under 6 | 27 | 2.2 | 1.3 |
| | 1264 | 100.0 | 60.9 |

The columns of world percentages in the tables show some interesting relations that help to give perspective on the worlds oil fields. Mexico and New Mexico produced nearly the same percentage of the worlds total in 1939. Michigan, Wyoming and Arkansas each produced about the same as Colombia. Kansas produced nearly as much as the Netherlands East Indies—the oil fields which Japan chiefly depended on to supply her for the war.

These comparisons, it must be most carefully remembered, are for the year 1939. Oil fields are not static. They have a large early production, then they fall off at first rapidly and then gradually, tapering off to exhaustion. War necessities for secrecy do not permit us to know 1943 details of production in other countries than our own. With the tremendous productive activities in Russia, Iraq and Iran,

and the destructive activities in the Axis fields by Allied air forces it is certain that the 1939 picture no longer is true. Russia, Iraq, and Iran are undoubtedly producing much more than in 1939. It is very doubtful if Rumania can be producing as much as in 1939.

The use of petroleum is chiefly as fuel for internal combustion engines. Its job in the last century had been to furnish light. When the gasoline engine made the automobile possible the far greater job of rubber tired transportation was loaded on the shoulders of this efficient slave. It still furnishes a large amount of light in the many places not on an electric circuit.

Now a third great job for petroleum is beginning to take form—to furnish raw material for the chemical industry. All the coal tar products can be made more abundantly and often more cheaply from petroleum. We would have been short of explosives for this war if oil chemists had not found a way to make an abundance of toluene—the base of tri-nitro-toluene, abbreviated to TNT. Toluene from coal tar would have been seriously insufficient.

Our synthetic rubber program would have been impossible without the necessary products from the oil refineries. It is said that the amount of oil required for our synthetic rubber program is about half of 1% of our production. In August 1944 synthetic rubber was being produced at the rate of 836 thousand tons per year. This compares well with the half million tons of crude rubber we used in prewar days. Mr. Dewey, who not long ago resigned as the rubber chief and recommended the abolition of his bureau, has stated that he feels that the low cost synthetic plants will continue to operate in competition with natural rubber, and that high cost plants will be obliged to close down. He recommends, however, that all synthetic rubber plants be kept as insurance for post war years rather than dismantled.

Mr. President: I haven't the pleasure of knowing Mr.

Dewey personally, but I think he proved himself a great citizen. I hope the government follows his advice, and keeps the synthetic rubber plants for insurance for the future.

Mr. Hotchkiss: I agree with you heartily in both ideas.

The English rubber companies who control natural rubber are expressing confidence that their product will be able to undersell, and will be more desirable than synthetic material. It is too early for anyone to be sure which will be proven right. The new synthetic product is likely to prove a formidable trade adversary for it has all the advantage of tremendous quantities of cheap raw material, and modern research to improve quality and cheapen the cost of manufacture. The growing of natural rubber may suffer the same fate as indigo.

The chemical industry will undoubtedly find many new uses for oil in the years to come. In addition to the tremendous possibilities ahead for improving the efficiency of motor fuel, oil now is able to furnish almost everything but the metals that go into a car. It can provide the finish paints, the artificial leather for top and upholstery, the non-shatter glass, the antifreeze, as well as the tires, oil and gasoline to make it go.

Alcohols of many kinds, including the kind used for beverage, can be made more cheaply from oil than from any other source, and of the highest purity. This may some day be an important factor in the food supply, by replacing grain now used for fermenting.

Many of the coal tar products can be made from petroleum as well as others that cannot be made from tar. The whole field of organic chemical industry has in oil a raw material the use of which is limited only by the ingenuity and energy applied to it. And this material is cheaply available in quantities far surpassing any other.

Will you show us the next chart boys?

Bob: We have a chart showing the uses of refinery products, if that is the one you want?

Mr. Hotchkiss: That's it. Thank you. You can show the chart with the percentages of refined products next.

The major products sold by the oil refineries for consumption in the United States in 1939 were of course dominated by motor fuel. The amounts given in table XXII do

TABLE XXII

U. S. Consumption of Refinery Products 1939

(In millions of barrels unless otherwise stated)

| | |
|---|---|
| Motor fuel | 552.6 |
| Residual fuel oils | 320.9 |
| Gas oil, and distillate | 138.8 |
| Kerosene | 60.5 |
| Lubricants | 23.6 |
| Road oil | 7.8 |
| Other finished products | 2.2 |
| Wax | 325.5 |
| millions of pounds | |
| Coke | 1.4 |
| millions of tons | |
| Asphalt | 4.9 |
| millions of tons | |

TABLE XXIII

Percentages of Refined Products, 1939

| | |
|---|---|
| Gasoline | 45.0% |
| Residual fuel oil | 24.7 |
| Distillate fuel oil | 13.1 |
| Kerosene | 5.5 |
| Lubricating oil | 2.8 |
| Wax | .1 |
| Coke | .7 |
| Asphalt | 2.2 |
| Road oil | .6 |
| Still gas | 5.5 |
| Other | .2 |

not include any exports, nor do they include crude oil sold for burning under boilers, either ship, locomotive, or stationary.

Table XXIII shows the results from running an average barrel of crude oil through the refinery.

Behind that statistical 45% heading the table there lies a dramatic instance of that measure of civilization, the "application of science to the common affairs of life." In 1912 it was discovered by a research man that by distilling crude oil under pressure, thus permitting the use of higher temperatures, a larger yield of gasoline could be obtained. This "cracking" process as it was called, like all new things, interfered with and upset established practices. Those who were doing "well enough, thank you" wanted no cracking process in their refineries. Others took it up gradually as their needs dictated. By the time of World War I, cracking had made a fair start. In the '20's it was more generally adopted so that the yield of gasoline increased in the last years of the decade to more than 40% of the crude. Now all the gasoline possible with present knowledge is extracted from every barrel of crude oil. Were it not for this method we would require more than double our present crude oil production to furnish the gasoline we now make. Here, as in many other instances, improved practice has resulted, in effect, in greatly increasing our mineral resources.

### *Other Non-metallic Mineral Resources*

If, as in the childhood game, everything is classified as "animal, vegetable, or mineral" such vitally important resources as water, air, soil, heat and light from the sun and all such would have to be included here. These resources are not bought and sold and consumed in the way that metals and fuels are. In our ordinary thoughts and in our dependence on them we look on these as inexhaustible, and free. They are, in a sense. What could be more free than sunlight and air.

Soil we are beginning to realize is exhaustible, but even wider understanding of this fact is necessary before we will use our soil resources with adequate intelligence. That water is a resource which for practical purposes is exhaustible is a fact that is understood by people only in very special cases. It can hardly be said to have entered the general public consciousness at all. In desert areas men learn to conserve the little water that exists there. Tribal wars have been fought to control desert wells. Industries in many cases have learned that the water available in a given locality is not sufficient to permit their expansion. This matter of water will be handled more intelligently only when people realize that it is a limiting factor on the concentration of population. New York City has had to go about 140 miles to get adequate water. Los Angeles has had to go over 300 miles, and but for federal government development of Boulder Dam and that opportunity to get water from the Colorado River on California's eastern boundary it might soon begin to feel the serious lack of water. On the other hand the cities along the Great Lakes have no worries as to sufficiency of their water supply.

These so-called inexhaustible resources are of vast industrial importance. But since they are not sold in the market by the ton or pound or barrel their importance escapes the popular attention that their value warrants.

There are other important non-metallic mineral resources that, in a similar sense, may be considered inexhaustible. It is impossible to think of exhausting all the rock in the world. When we think of the sands of the seashore it is difficult to think of the world running short of sand. The other one of the three great mineral building materials is a manufactured product made from pure limestone and clay, and from blast furnace slag. I refer to cement. It is similarly out of the question to think we can use up all the limestone and clay.

Exhaustibility of these abundant building materials is a matter of cost rather than shortage of material. In the broad sense this is true of all minerals—if we are able and willing to pay any cost, no matter how high, we can always have plenty of *almost* everything. The sand and stone used for our construction purposes is not always found near the place we need to use it. Usually the haulage to the job costs much more than the material is worth in the pit or quarry. For this reason it costs much more to build concrete roads in Iowa or Illinois than it does in Wisconsin or other areas where suitable sand and stone is available in abundance in almost every locality, with relatively short hauls to the job.

*Cement* is made in 150 plants in thirty six of our forty eight states. In 1939 the shipments of portland cement were 122 million barrels (each barrel contains 376 pounds of cement) with a value of $181 million. Other kinds of cement were manufactured and shipped in relatively small quantities to raise the total of all kinds of cement to 125 million barrels valued at $184 million.

The 12 states that produced no cement in 1939 were New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, Delaware, North Carolina, South Carolina, North Dakota, Nevada, Arizona and New Mexico. These you will note are widely scattered and easily supplied from mills in adjoining states.

The uses of cement in different parts of our construction industry were estimated by the Portland Cement Association for 1938 to be as follows—

| | |
|---|---|
| Paving; roads, streets and airports | 24% |
| Bridges, railroads, and large buildings | 29% |
| Reclamation, water supply and sewerage | 17% |
| Small housing, and miscellaneous | 20% |
| Farm uses | 10% |
| | 100% |

Cement presented no difficulties in relation to war needs. While much was needed, the shortage of manpower cut down paving, bridge construction, housing, and other normal uses.

The world production is given in metric tons of 2204 pounds. In 1938 the United States led with 18 million tons. Germany was second with 15 million, United Kingdom third with 8 million, and Russia fourth with 6 million. Twenty five countries in Europe produced cement. Fifteen countries in Asia, 8 in Africa, 2 in Oceania and 9 in South America. In addition Canada, Cuba, Guatemala, Mexico and Puerto Rico produced cement in North America in 1938. The world production was 89 million tons.

*Stone* is one of the oldest building materials used by man. Today we use it in two chief forms—"dimension" stone, cut to various sizes and shapes and used for construction purposes, for monumental purposes, paving blocks, curb and flag stones. Of this we used 2.3 million tons in 1939, worth $25.6 million.

The greatest use of stone is for crushing. In this form stone is used for concrete, which used 94 million tons in 1939, nearly $\frac{3}{4}$ of all the crushed stone; for furnace flux (limestone) which is the next largest use, taking 13 million tons; for riprap to prevent erosion, for refractory lining in furnaces, for agricultural lime and other purposes. The total crushed stone used in 1939 was 145 million tons valued at $133 million. All stone used, both dimension and crushed, amounted to 147 million tons worth $158 million.

Slate for roofing, flags and similar uses added 180 thousand tons worth $4 million in '39. In the form of crushed slate, granules, and flour, slate added also to the total for stone 352 thousand tons worth $2.6 million.

*Sand and Gravel* exceeded stone in tonnage with a total of 195 million tons, but its total value was less than stone, being $95 million.

Gravel is used for making concrete and for railroad ballast chiefly. Sand has a wide variety of uses, for making glass, molds for casting, concrete for all purposes, grinding and polishing, filters, engine sand, and others.

Undoubtedly a considerable total of sand and gravel is used by small local builders and farmers that is never reported so the above figures must be considered as covering reported uses only.

*Gypsum* is a light colored to white rock occurring like limestone which it resembles. It is sulphate of lime. Calcined and ground it becomes the familiar plaster of Paris, which the ordinary citizen sees used to make casts to set broken limbs, or to make dental impressions. Its greatest use is as a building material as an ingredient of plaster, as lath, wallboard, gypsum tile for interior partitions, and as a constituent of Keene's cement.

The uncalcined ground gypsum is used as "landplaster" on the soil as a fertilizer, and in portland cement to retard setting. It is also used as a paint filler. These uses in 1939 consumed 868 thousand tons valued at $1.9 million.

The calcined gypsum used for building purposes in 1939 was 3.1 million tons valued at $42.6 million. For industrial purposes it was used by makers of plate glass and terra-cotta, by potteries, by doctors and dentists, and for statuary and other uses.

Total uses of calcined gypsum in 1939 were 3.2 million tons valued at $44 million.

*Lime* is another familiar abundant mineral building material. Like gypsum it is used as a fertilizer. Its greatest use is in the chemical industry which used, in 1939, 2.2 million tons for a multiplicity of purposes such as bleaching paper pulp, sugar refining, tanning, water purification, glass making, calcium carbide, petroleum refining, and many others. Building purposes made the second largest use with 1 million tons. Third was 0.7 million tons

for refractory linings for furnaces—dead burned dolomite, a variety of limestone containing the carbonates of both lime and magnesia.

Total lime used in 1939 was 4.3 million tons valued at $30 million.

*Clay* is almost too common for us to think of it as a mineral resource, yet many kinds of it have such valuable uses and are so uncommon that they bring a good price, some specially fine kaolin china clays selling for more than $15 per ton. Some fire clays sell for over $6 per ton but the average in 1939 was about $2.60. A fire clay imported from Bavaria cost $38.50 per metric ton delivered at United States Atlantic ports, and the buyer had to pay 25% additional for duty. So we can have more respect for "common clay" than we had heretofore.

In 1938 nearly 6 million tons of various kinds of brick, building tile, and sewer pipe were produced. This is by far the largest use of clay. Clay used for brick is not usually sold, but is burned at the pit, so this clay is not included with the kinds that are sold by the producer of the clay. Such clay, mined and sold in 1939, totalled 3.9 million tons, and was valued at $17 million.

Clays of various kinds have many uses, as filler for paper, filler for rubber, for linoleum and oilcloth, as filler in paints, in cement making; as a wide variety of refractories, such as fire brick, crucibles, retorts for zinc smelters, foundry facings; and for many other uses, mud for drilling oil wells, filtering and decolorizing, enameling, abrasive making, and chemicals, not to attempt to name them all.

*Abrasives* of a number of kinds are produced in the U.S. Some of them are natural and some are manufactured. Of the natural abrasives some are silica used in the form of fine grains or powder such as diatomite, tripoli, quartz and ground sand and sandstone. Some are silica used in larger forms such as grindstones and pulpstones, oilstones, whetstones, millstones, and flint lining and grinding pebbles for

grinding ore and other hard materials. Natural abrasive minerals other than silica, which we produce, are pumice, garnet, and emery. These natural abrasives we produced were sold for $3.8 million in 1939.

The manufactured or artificial abrasives in that year were worth nearly $6.5 million. They include silicon carbide $1.7 million, aluminum oxide $3.0 million, and metallic abrasives $1.8 million.

*Sulphur and pyrites* are the two great sources of sulphuric acid. Minor amounts of sulphur and sulphur products are recovered in the purification of natural and manufactured gas and from oil refining, but these are a negligible percentage of the total.

Sulphur is found in nature in two chief forms, as elemental sulphur, found in salt domes in our Gulf coastal area and in volcanic regions, and as sulphides of iron, copper, zinc and lead. The sulphur in both these forms is used chiefly to make sulphuric acid. The sulphur of the Gulf coast in Texas and Louisiana was found in drilling salt domes for oil. Hundreds of feet underground, and inaccessible because of the poisonous sulphur gases about it there was no way of recovering it until Herman Frasch, an oil chemist, devised a method of melting it in its underground site and pumping the molten sulphur to the surface. It is pleasant to report that his genius won him comfortable wealth.

Frash knew, of course, that sulphur melted a little below 250° Fahrenheit. If he could get heat down there in sufficient quantity the sulphur would melt and could be pumped to the surface. Water boils at 212°F. but under pressure can be heated much hotter without vaporizing. He heated water in high pressure boilers, well above the melting point of sulphur, pumped it into the deeply buried sulphur and found his theory worked. Two large deposits totalling more than 25 million tons have been worked out and other large deposits totalling more than 50 million tons have been put into production.

The Frash process, applied to the large Gulf coast deposits, made the United States the world's greatest source of elemental sulphur.

The United States in 1939 shipped to consumers 2,233,817 long tons of sulphur. Of this 652,824 long tons were exported. The other chief producers were Italy and Japan, both of which mined sulphur in volcanic regions. Nowhere but in the United States, as yet, has there been found salt dome sulphur such as ours. Italy's production in '38 was less than $\frac{1}{6}$ of ours and Japan's about $\frac{1}{14}$ although no accurate statistics are available for Japan. World production, as distinguished from consumption, is estimated at 2,900,000 long tons in 1939, of which the United States produced 2,091,000 tons, or 72%.

Elemental sulphur is used for two chief purposes in addition to the making of sulphuric acid—for rubber manufacture, which used 49,000 tons in 1939, and as a fine powder for insecticides. The elemental sulphur consumed in the United States in '39 went to the following industries.

May we have your charts showing the uses of sulphur and the consumption of sulphuric acid?

Dick: These are the ones.

TABLE XXIV

United States Consumption of Sulphur by Industries in 1939
(In thousands of long tons)

| | | |
|---|---|---|
| Chemicals | 695 | 43.5% |
| Fertilizer and insecticides | 370 | 23.2 |
| Pulp and paper | 240 | 15.0 |
| Explosives | 64 | 4.0 |
| Rubber | 49 | 3.1 |
| Paint and varnish | 49 | 3.1 |
| Dyes and coal tar products | 40 | 2.5 |
| Food products | 6 | .4 |
| Miscellaneous | 82 | 5.2 |
| | 1,595 | 100.0 |

TABLE XXV
United States Consumption of Sulphuric Acid by Industries in 1939
(In thousands of 2000 pound tons)

| | | |
|---|---|---|
| Fertilizer | 2,100 | 25.6% |
| Petroleum refining | 1,210 | 14.8 |
| Iron and steel | 980 | 12.0 |
| Chemicals | 975 | 11.9 |
| Coal products | 740 | 9.0 |
| Other metallurgical | 570 | 7.0 |
| Paints and pigments | 500 | 6.1 |
| Rayon and cellulose film | 400 | 4.9 |
| Explosives | 190 | 2.3 |
| Textiles | 116 | 1.6 |
| Miscellaneous | 400 | 4.8 |
| | 8,181 | 100.0 |

A comparison of the two foregoing tables for the consumption of sulphur and sulphuric acid indicates that the industries listed as consuming sulphur made it into sulphuric acid for the most part before using it.

The fertilizer industry, chief consumer of sulphuric acid, makes sulphur into acid to treat rock phosphate in order to change it into a more available plant food. The second and third largest consumers of acid, oil refining and iron and steel, do not appear as consumers of sulphur in Table XXIV as they purchased their sulphur mostly in the form of acid.

Sulphuric acid is made by burning sulphur or by roasting pyrites, or as a by-product from the smelting of ores, chiefly copper and zinc. Pyrites, or sulphide of iron, we imported from Spain and Canada, chiefly, (with 23 thousand tons from Greece) to the total of 482 thousand long tons in 1939. We produced 516 thousand long tons of pyrite in the United States in that year. It contained 42.2% sulphur.

World production of pyrite for sulphuric acid manufacture is widely distributed geographically. Twenty three

countries are listed by the Bureau of Mines as producers in 1938. Twelve produced over 100,000 metric tons each, Spain leading with 1,635 thousand tons. Norway had 1,028 thousand tons, Italy 930 thousand, United States 565 thousand, Cyprus 524 thousand, Portugal 558 thousand, and Germany 465 thousand.

Lesser producers in central Europe have undoubtedly given Germany a sufficient supply for her war needs.

*Phosphate rock* and basic steel slag are the sources of phosphate fertilizer. This is of great importance in the food production of the world. Basic slag takes the harmful phosphorus out of steel. It supplies 70% of the phosphorus of the German fertilizer industry. In addition Germany imported in '38 over one million tons of phosphate rock which is now cut off. Japan imported about 600 thousand tons, and produced about 300 thousand tons at home in 1938. Her imports are also largely stopped by the war.

United States production of phosphate rock comes largely from Florida which in 1939 produced 2,679 thousand long tons, worth $7,893,000. Tennessee was second with 938 thousand tons worth $3,857,000. Montana and Idaho together produced 140 thousand tons, worth $544,000. These totalled 3,757 thousand tons, worth $12,294,000, of which we exported 949 thousand tons worth $5,223,000.

The three elements necessary for fertilizer are phosphorus, nitrogen and potash. Nitrogen is present in manure, and slaughter refuse. It is also artificially combined from the air. Another important source of nitrogen of great importance is growing legumes, such as clover. Potash occurs in association with salt deposits—the remains of dried up seas—and in salt lake brines. Germany and Chili were once the worlds only sources, but since World War I resources in our western deserts have been developed that make us independent of foreign sources.

*Salt* is a much larger business than one would think

whose only acquaintance with it is at the table. It is an important base of chemical industry, the source of the chlorine used in so many forms. Salt is widely distributed over the world. It is produced from sea water, mined as rock salt, and pumped to the surface as brine. In 1939 the United States produced 9,278,000 tons of 2000 pounds each. Total value was $24.5 million.

Seventy six countries produce salt. It is produced in every continent in ample supply.

Salt furnishes to the chemical industry the basic material from which to make chlorine, caustic soda, and combinations of these with other elements. Soda ash, the commercial name of the carbonate, finds important use in the glass, pulp and paper, caustic soda and other industries. It is used for water softening and petroleum refining, for soap, lye, textile and rubber reclaiming industries. Food preserving is the largest market for dry salt.

Salt is one of the mineral resources of which there is an inexhaustible supply.

*Minor non-metallic* minerals, which are used in comparatively small quantities, but which nevertheless have vital functions in our industry that cannot easily be filled by substitutes, make a goodly list. Only the more important are mentioned in the table on page 138.

May we have the chart showing the minor non-metals, boys?

Bob: Right here, sir.

The war rating in the table was established by the government as war needs required. A "strategic mineral" is one of which supplies must all or nearly all be imported, and for which the use must be strictly controlled. A "critical mineral" is one which is more adequately suppliable from domestic sources, or for which the need is not so urgent, and for which a less strict control will be sufficient to insure war supplies.

## TABLE XXVI

Consumption, Imports and Uses of Minor Non-metals, 1938 or '39

| *Mineral* | *Consumption, Thousands of Tons* | *Value, Thousands of Dollars* | *Imports* | | *Chief Uses and War Rating* |
|---|---|---|---|---|---|
| | | | *Thousands of Tons Source* | *Percent of Consumption* | |
| Mica splittings and sheet | 2.6 | 1,500 | 2.0 India Madagascar Canada | 78 | Radio, airplane spark plugs, condensers. Strategic mineral. |
| Mica, ground | 35.2 | 1,186 | 4.3 Canada United States | 12 | Roll roofing, wall paper, paint. Ample supply. |
| Quartz crystal | ? | ? | Brazil | 100 | Radio frequency control. Strategic mineral. |
| Asbestos | 256 | 9,388 | 243 Canada | 94 | Brake lining, clutch facing, packing, fireproof textiles, heat insulation. Critical mineral. |
| Graphite | 22 | 425 | 20. Ceylon Madagascar | 90+ | Iron and steel, pencils, crucibles, lubricants. Critical mineral. |
| Cryolite | 10 | 700 | 10 Greenland Germany France | 100 | Aluminum production. Glass, enamels, insecticides. Critical mineral. |
| Fluorspar | 198 | 3,631 | 18 France Newfoundland Mexico | 9.1 | Iron and steel, 70%; enamel 12%, hydrofluoric acid, 15%. Critical mineral. |
| Talc, soapstone | 280 | 3,126 | 26. Italy Canada France | 9.0 | Paint, ceramics, rubber, roofing, paper. Not critical. |

## *Summary of Non-metallic Minerals*

Even though we do not realize it all these non-metallic minerals are used to furnish services for each one of us. We are reasonably familiar with the major services that we get from crude petroleum. We know it is refined to furnish us gasoline and lubricating oil to run our cars, trucks and airplanes, both for civilian and military purposes. We know part of it drives our ships, both peace and war varieties. Part of it we use to heat our houses, part to enrich the gas for our kitchen ranges. A small part now goes to make rubber tires. The lesser services we get from oil are mostly unknown to us. But all these things are produced for us, and passed on to us for our benefit, by people who have the knowledge and skill to do these things. If we were presented with a barrel of crude oil and told we must make our own gasoline, lubricating oil, and tires, we would be helpless. That barrel of oil would be useless to us.

This illustration serves for all the other non-metallic minerals. No one of us has the knowledge or skill to use them all. Every one of us individually is at the mercy of everybody else collectively. It takes *all the knowledge* and *all the skill* and *all the energy* that *all of us possess* to render the services that *all of us need.*

If the relatively small part of us that are engaged in oil refining should refuse to do the job before us, the rest of us would be unable to do it for ourselves, and so would have to do without. We could not run our cars or trucks or busses. The many oil driven locomotives would stop and the freight they brought us would no longer come. A similar statement could be made with regard to every commodity we use. To keep the big machine going that supplies us all with our needs requires ALL the BRAINS and SKILL and ENERGY that ALL of us possess. No small group of men could possibly know enough to tell all the rest of us what to

do and how to do it. In that fact lies the impossibility of successful government bureau operation of business affairs.

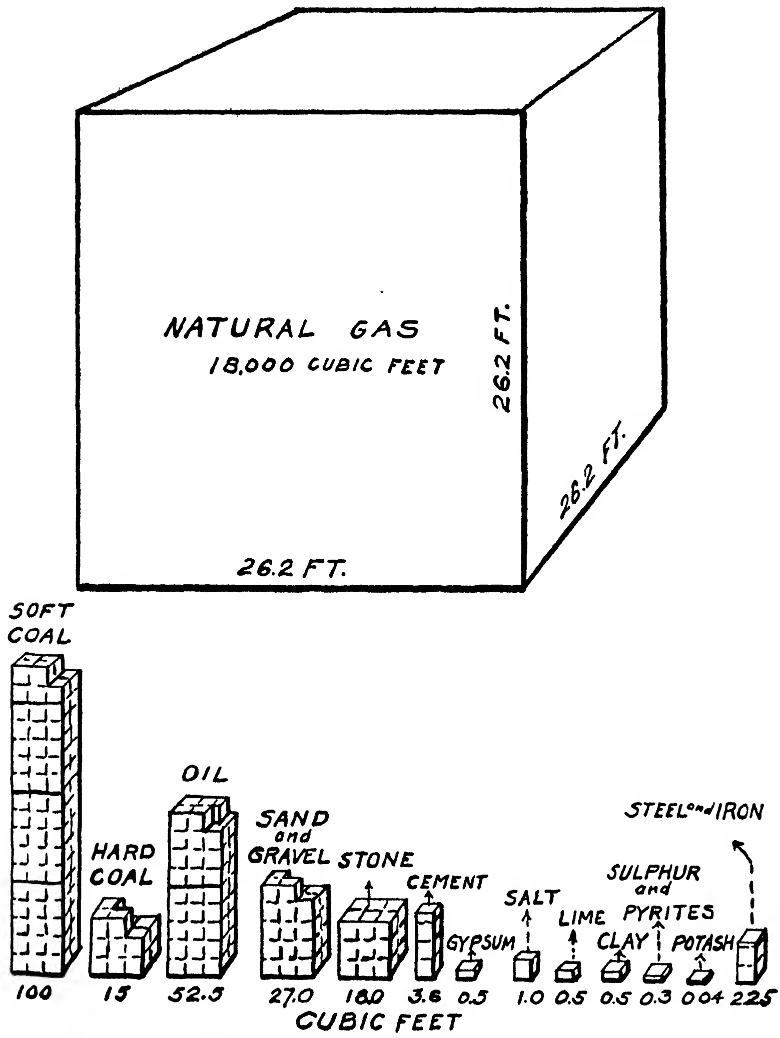
Realizing this fact—that it takes ALL the BRAINS and SKILL and ENERGY of ALL of us to produce the things required, it will be interesting to see what each of us would have to work with if he himself had to do everything for himself.

Table XXVII gives the quantity of each non-metallic mineral produced for each man woman and child. It gives the value at the place where it is produced. To use each product at our home each would have to pay the freight and delivery charge in addition to the cost at the point of production. This would, on the average, be considerably more than the value given. No attempt has been made to be meticulously accurate with these figures, but they give a fair general picture.

Will you boys show us now the table of quantities and values of non-metallic minerals that each of us would have if the total production of the United States were divided equally between us, so each man, woman, and child of the 135 million of us would have the same amount?

Dick: Here it is sir. When we made it we wondered what we would do with our shares.

(See pages 141 and 142)




*Number of cubic feet of important non-metallic mineral products used by or for each man, woman and child in the United States in* 1939. *The cubic feet of iron and steel used is added for comparison.*

TABLE XXVII
Non-metallic Minerals
(Per capita quantities and value, 1939)

| *Mineral* | *Quantity* | *Value* |
|---|---|---|
| Crude petroleum | 392 gallons | $ 9.50 |
| Natural gasoline | 16 " | .67 |
| Natural gas | 18.6 thousand cu. ft. | 3.95 |
| Total liquid and gas fuels | | $14.12 |
| Coal | | |
| Bituminous | 5,800 pounds | 5.38 |
| Anthracite | 760 " | 1.38 |
| Total coal | 6,560 " | $ 6.76 |
| Construction material | | |
| Cement | .9 barrel | 1.33 |
| Stone and slate (including stone used for other purposes) | 2,200 pounds | 1.22 |
| Sand and gravel | 3,400 " | .78 |
| Total construction material | | $ 3.33 |
| Sulphur and pyrites | 39.7 pounds | .27 |
| Lime | 64. " | .22 |
| Salt | 138. " | .18 |
| Mineral paint pigments | 2.7 " | .15 |
| Clay for refractories and pottery | 60 " | .13 |
| Gypsum | 61 " | .13 |
| Phosphate rock | 56 " | .10 |
| Potash | 5.4 " | .09 |
| Fluorspar | 2.7 " | .027 |
| Talc and soapstone | 3.8 " | .02 |
| Abrasives | 2.5 " | .014 |
| Magnesite | 2.8 " | .01 |
| Others | | .95 |
| | | $25.55 |

## CHAPTER 6

# Reserves of Mineral Resources

AFTER getting the facts on production and use of the worlds mineral resources, we are prepared to discuss a subject which you, Mr. Banker, and Mr. Manager, have had in the back of your minds since this discussion started. We have used so much of our resources in the last generation, that we all would like to have some notion of what the future holds for us. Of most of our resources we have used more in the last thirty years than we had used before in all history—more in 30 years than in the preceding 30 centuries.

Mr. Banker: I am very much interested in this matter of the existing reserves of various mineral resources. I am not alarmed particularly about a supply of iron ore to keep our steel plant going during the rest of my life time, which wont be too many years now. But as a citizen who realizes somewhat, at least, how important a part our mineral supply plays in our general welfare I should like to be assured that there is plenty for all the future.

Mr. Hotchkiss: I'm afraid no one can give you any such assurance. But we can at least look over the field and see where we stand.

As has been pointed out in discussing the production of various mineral resources, there are some of these that are inexhaustible. Others are found in more limited amounts that will last, as in the case of coal, for several thousands of years at present use rates. Some, such as petroleum, natural gas, tin, zinc, lead, copper, iron, manganese, and

many of the lesser minerals, are so limited in quantity that, at present use rates, a few decades for some to a century for others will exhaust known supplies.

The list of inexhaustible mineral supplies includes such plentiful non-metallic things as building stone, sand, gravel, clay, cement, gypsum and salt. It is beyond our imagining to think of uses so great as to make serious inroads on the supply of these. Individual deposits of such non-metals will be worked out, it is true, but others can be found not so far away as to make them unavailable.

Among the metals magnesium is the only one we can say is inexhaustible. Cheaply extracted from sea water, there is no visible end to a supply to meet a need as great as we can imagine. Aluminum is inexhaustible if we extract it from clays and other abundant, common alumina silicate sources. But the present much cheaper source is the oxide, bauxite, and this appears to be so limited in extent as to be exhaustible in a few generations.

When we say that a certain mineral resource is exhaustible we need to define what we mean. We need to have clearly in mind that many parts of the world have been examined only very cursorily, and that for many countries we only know the skeleton of the geological facts. These cursory examinations tell us much that is definite, such as the fact that there is no appreciable coal to be found in rocks older than the Carboniferous era. Most of the world is well enough known to tell whether or not there are possibilities for coal in a given area. But the scant knowledge we have cant tell us that there never will be found further supplies of most other economically valuable minerals.

The United States and western Europe are fairly well known, and have been quite thoroughly searched for minerals. The chance is very slight that there may exist in either area unknown, large, workable deposits of coal, iron ore, manganese ore or copper ore. As to petroleum

the facts known are not so definite, but the chance of finding any but small production is rather remote for western Europe, but more hopeful for the United States.

The rest of the world is less well known. With much certainty we can state the possibility of finding there other large oil fields than those we now know.

The possibility of finding new great iron ore fields to compare with those of Lake Superior, India, Brazil and France is very remote, but still cannot be written off as impossible. Iron ore deposits are large and not so easily nor so well hidden as the small deposits of many other metals.

So we know much about the world potentialities of coal and iron ore. We know less by far of the potential supply of petroleum and natural gas for the future. We know too little to make a valid estimate of the potential supplies of copper, lead, zinc, bauxite for aluminum, tin, mercury, nickel manganese, sulphur, fluorspar, and the list of lesser minerals.

It is fortunate that our knowledge is extensive as to coal and iron ore. These are the two great factors in our machine age economy. Our lesser knowledge of other mineral resources is compensated in some considerable degree by the fact that there are greater possibilities for the discovery of at present unknown supplies.

Another important matter to be held in mind in thinking of future mineral supplies is that there are two kinds of uses. One is the use that destroys the mineral. This is the case with coal, petroleum, and gas, which are burned. It is true with such uses as metal base paints of zinc and lead, and galvanizing, all of which uses result in only one service for the metal. The other is the use that does not destroy the mineral. This is the case with most of our uses of metal. They are subjected to minor loss by corrosion and wear, but the greater part of the metal is not used up. When its

usefulness in a particular article is past, due to wear, or becoming outmoded, it is available for remelting and re-use.

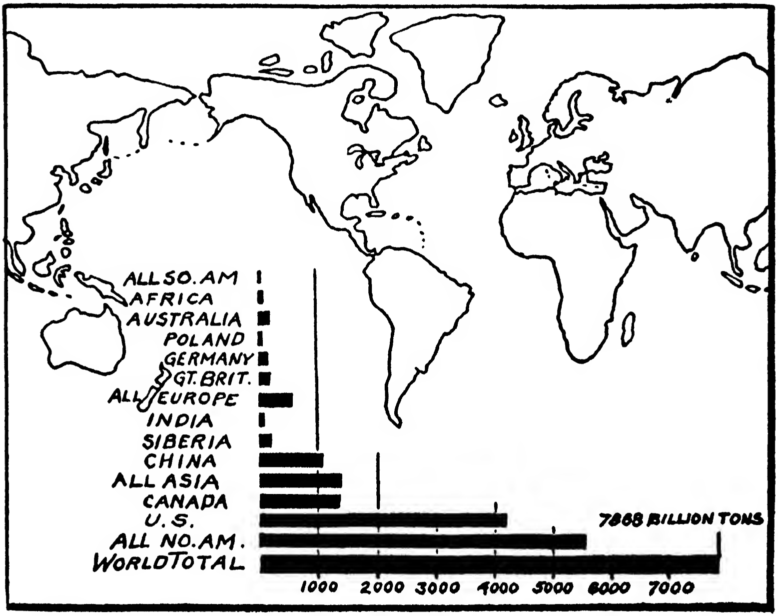
Most of our metals can be looked upon as being taken from our *underground* supply, and being added to our *overground* supply. From this viewpoint we have been building up reserves above ground. If demand for a metal were to become static it is easy to imagine its use over and over again, with new metal from virgin ores being necessary only to replace that worn or corroded away and that lost as small pieces not worth recovering. It is estimated that we have now in use in the United States over a billion tons of iron and steel, ten times our annual wartime demand and nearly twenty times our annual peacetime demand. Our past production of other metals makes rough guesses possible, —that we may have in use possibly 15 to 20 million tons of copper, 10 to 15 million tons of lead, 3 to 5 million tons of zinc, and various alloy metals from which much may be recovered to lessen future demand for virgin metal from ores.

The recovery of secondary iron is now about half of our wartime steel need. Secondary copper in 1939 was $\frac{2}{5}$ of our total production. Secondary lead was about a third, secondary zinc was somewhat less than a third, and secondary tin (recovered mostly from tin alloys rather than from tin sheet) was also a bit less than a third of the total of this metal we had for our use.

Two world wide estimates of mineral resources have been made. The first was an estimate of the iron ore resources in 1910, by the committee of the Eleventh International Geologic Congress. The second was an estimate of the coal resources in 1913 by the Twelfth International Geologic Congress. In 1935 a statement of *known* copper ore reserves was presented to the Sixteenth International Geologic Congress, but this could not attempt to be at all definite, as the other two had been, as to total reserves.

*World Coal Resources*

In making the estimates for the Geologic Congress it was recognized that there could be no high degree of accuracy.




*World Coal Reserves.*

The results could only be the best estimates that the best qualified men could make. It is probable that these estimates are least accurate for Asia and most accurate for western Europe. But they are ample for our purpose of a general picture. The Congress estimates were revised in 1929 for the Encyclopaedia Brittanica by R. Dawson Hall, Engineering Editor of *Coal Age*. The figures given in the table are from Hall. Countries are as of 1929.

Will you boys show us the chart you made of world coal resources?

Boys: Here it is, sir.

TABLE XXVIII
World Coal Resources
(In millions of 2000 pound tons)

| | | *World Percentage* |
|---|---|---|
| United States | 4,231,076 | 53.8 |
| Canada | 1,354,512 | 17.2 |
| Other North America | 655 | |
| Total North America | 5,586,243 | 71.0 |
| Colombia | 29,762 | .4 |
| Peru | 2,248 | |
| Chile | 3,360 | |
| Venezuela and Argentine | 12 | |
| Total South America | 35,382 | .4 |
| United Kingdom | 182,308 | 2.3 |
| Germany | 163,415 | 2.1 |
| Poland | 75,871 | 1.0 |
| Ukraine | 61,351 | .8 |
| Czechoslovakia | 26,999 | .3 |
| France | 20,478 | .3 |
| Belgium | 12,125 | .1 |
| Norway incl. Spitzbergen | 9,645 | |
| Spain | 6,104 | |
| Jugoslavia | 4,905 | |
| Russia | 2,191 | |
| Netherlands | 1,887 | |
| Rumania | 800 | |
| Hungary | 673 | |
| Austria | 428 | |
| Bulgaria | 428 | |
| Italy | 272 | |
| Sweden | 126 | |
| Denmark | 55 | |
| Greece | 44 | |
| Total Europe | 570,105 | 7.3 |

TABLE XXVIII.—(*Continued*)

| | | *World Percentage* |
|---|---|---|
| Korea | 89 | |
| China | 1,097,446 | 13.9 |
| Japan | 8,785 | |
| Manchuria | 1,332 | |
| Siberia | 191,669 | 2.4 |
| Indo-China | 22,048 | .3 |
| India | 87,084 | 1.1 |
| Persia | 2,048 | |
| Total Asia | 1,410,501 | 17.9 |
| Belgian Congo | 1,091 | |
| Southern Nigeria | 88 | |
| Rhodesia | 7,632 | |
| South Africa | 61,950 | .8 |
| Total Africa | 70,761 | 0.9 |
| Australia | 189,284 | 2.4 |
| New Zealand | 3,732 | |
| British North Borneo | 83 | |
| Netherland India | 1,445 | |
| Philippines | 73 | |
| Total Oceania | 194,617 | 2.5 |
| Total for World | 7,867,609 | 100.0 |

To us the outstanding fact shown by the table is the preponderance of the United States, which has over half the coal resources of the world. This is enough to last us, at recent rates of consumption, from 7000 to 10,000 years.

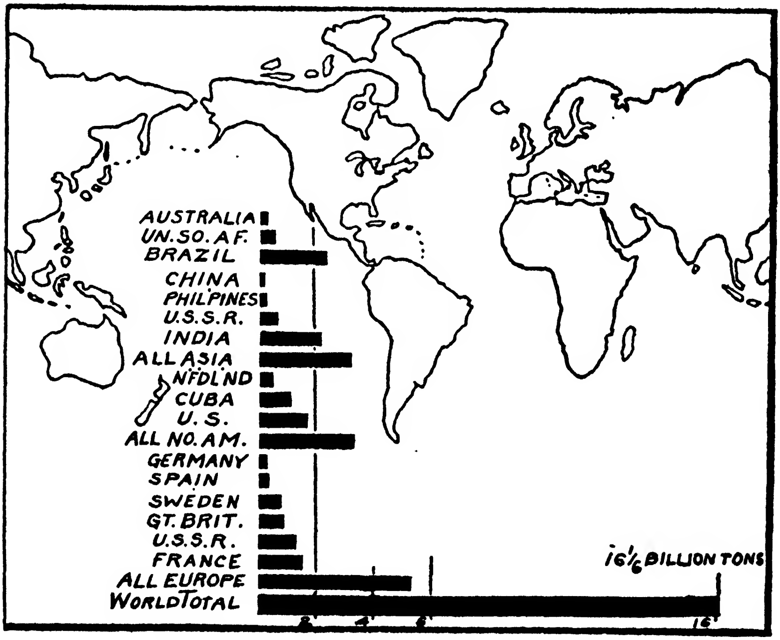
The coal of the rest of the world, at recent rates of their consumption, will last 4,000 to 5,000 years. Africa and South America have relatively little and seem destined to be limited to industries fitted to this condition.

These supplies are large enough to last the world for a

period into the future as long as recorded history, if we use them at present rates. There is no doubt however that the need for power, transportation, and steel will increase as the more backward people come nearer to the living standards of the most advanced. This will use coal faster than at present and shorten the period it will last by whatever this demands. The only way this trend is likely to be contravened is by improving the efficiency of its use. However the time is far in the future when serious shortage of coal will face those who follow after us.

### *World Iron Ore Resources*

The estimate made of iron ore reserves by the Geologic Congress in 1910 stimulated many studies all over the




*World Iron Reserves given as metal in the ore.*

world, and much has been written since 1910 in revision of that estimate. These revisions have been put together and published in January 1944 by Harry Mikami in *Economic Geology*. These figures are the basis for the table following.

In order to give figures in which low grade and high grade ores can be fairly compared I have reduced them to metallic iron content of the ores, using Mikami's figures where available and estimating the iron content in those few cases where he gives no figures.

It must be borne in mind that these estimates are made by many individuals, each on his own ideas. There is no uniformity of plan in making the estimates. Many are undoubtedly conservative and others probably are overly optimistic. Such as they are they make the best information we have. These revised estimates differ somewhat from those of 1910, chiefly in large additions to the reserves in India and Siberia, but in most ways they do not seriously change the 1910 figures. They serve adequately our present purpose to get the best picture available for the world's future supply of iron.

Boys, we are ready for your chart of the worlds iron ore reserves.

Bob: Here it is, sir.

This table gives a large mass of figures that are well worthy of study. They and the coal figures make the best basis we have, and a very dependable one at that, for prophesying the future prosperity, and political and military power of the various countries.

The "Actual Reserve" column shows the estimates of ores of the kind now being used. By referring to the steel production table, page 71, you can see which countries are using their ores most rapidly now. Of the countries having large actual reserves the United States and Europe, including Russia, are using large quantities of their actual reserves.

Those of Cuba (because of undesirable qualities), Brazil (because of their remoteness), and the lesser ones are being used much less extensively than the ores of the United States and Europe.

TABLE XXIX
World Iron Ore Reserves
(Metal content, in millions of tons)

| | *Actual Reserves* | *Percent of World* | *Potential Reserves* | *Percent of World* |
|---|---|---|---|---|
| North America | | | | |
| Canada | 50 | .... | 3,500 | 5.8 |
| Cuba | 1,200 | 6.9 | 3,600 | 6.0 |
| Mexico | 60 | .... | 40 | |
| Newfoundland | 500 | 3.1 | 800 | 1.3 |
| United States | 1,710 | 10.6 | 23,450 | 39.1 |
| Total North America | 3,520 | 20.6% | 31,390 | 52.2% |
| Europe | | | | |
| Albania | 10 | | | |
| Czechoslovakia | 22 | .... | 30 | |
| France | 1,575 | 9.7 | 2,100 | 3.5 |
| Finland | ...... | .... | 32 | |
| Germany | 256 | 1.6 | 600 | 1.0 |
| Austria | 70 | .... | 60 | |
| Great Britain | 930 | 5.8 | 2,100 | 3.5 |
| Greece | 50 | .... | 22 | |
| Hungary | 32 | .... | | |
| Italy | 30 | | | |
| Norway | 105 | .6 | 300 | .5 |
| Poland | 42 | .... | 50 | |
| Portugal | 22 | .... | 30 | |
| Rumania | 10 | | | |
| Spain | 360 | 2.2 | 350 | .6 |
| Sweden | 775 | 4.8 | 750 | 1.2 |
| Switzerland | 6 | | | |
| U.S.S.R. in Europe | 1,395 | 8.6 | 5,250 | 8.8 |
| Yugoslavia | 35 | | | |
| Total Europe | 5,725 | 33.3% | 11,674 | 19.1% |

TABLE XXIX.—(*Continued*)

| | *Actual Reserves* | *Percent of World* | *Potential Reserves* | *Percent of World* |
|---|---|---|---|---|
| Asia | | | | |
| China | 200 | 1.2 | 245 | |
| India | 2,160 | 13.4 | 3,500 | 5.8 |
| French Indo China | 25 | | | |
| Japan | 28 | | | |
| Korea | 24 | .... | 90 | |
| Malaya | 41 | | | |
| Neth. E. Indies | 45 | .... | 450 | .8 |
| Philippines | 235 | 1.5 | 150 | |
| Turkey | 10 | .... | 10 | |
| U.S.S.R. in Asia | 630 | 3.9 | 720 | 1.2 |
| Total Asia | 3,398 | 20.0 | 5,165 | 7.8 |
| Australia | 240 | 1.5 | | |
| New Caledonia | 10 | | | |
| Total Oceania | 250 | 1.5 | | |
| South America | | | | |
| Brazil | 2,400 | 14.8 | 4,400 | 7.3 |
| Chile | 72 | | | |
| Colombia | ...... | .... | 19 | |
| Peru | 60 | | | |
| Venezuela | 60 | .... | 450 | .8 |
| Total South America | 2,592 | 14.8 | 4,869 | 8.1 |
| Africa | | | | |
| Algeria | 80 | | | |
| Tunisia | 15 | | | |
| Fr. Morocco | ...... | .... | 18 | |
| Sp. Morocco | 16 | | | |
| Fr. Guinea | ...... | .... | 1,125 | 1.9 |
| Rhodesia | ...... | .... | 1,500+ | 2.5+ |
| Sierra Leone | 11 | .... | 1,100+ | 1.8+ |
| Union So. Africa | 550 | 3.4 | 3,150 | 5.2 |
| Togo | ...... | .... | 10 | |
| Total Africa | 672 | 3.4 | 6,903 | 11.4 |
| World Total | 16,157 | 100% | 60,001 | 100% |

The "Potential Reserve" column shows the estimates of ores of lower grade and other undesirable attributes, or far from using industries and subject to high transportation costs. These are ores less fully known and not at present being used. In this column you will note that North America owns 52.2% of the world's total, and that the United States alone owns 39.1% of the world's supply. While Europe possesses a third of the world's actual reserves it has only 19.1% of the potential reserves. Asia has as great actual reserves as North America, but only one sixth as much potential reserves. Asia can support a goodly steel industry in India and another in Siberia, with a lesser one in China that would hardly supply local needs as China advances in industrial development. South Africa and Australia have sufficient of both iron ore and coal to be fairly self sufficient. South America, because of lack of coal, is the only continent that must depend practically entirely on others for its steel supply.

The United States, England, western Europe and Russia are destined to continue to be the world's great steel producers with all that this implies in economic wealth, and political and military power. These will be the starting points of the world's future wars if they are unwise and stupidly and shortsightedly selfish, or they will be the seats of the world's great stabilizing influences for peace if they are wise and *longheadedly* selfish, willing to choose the profits of peaceful development along with the other great steel producers, instead of the apparently quick profits of conquest and plunder. Germany has twice chosen the latter course in the last generation, and each time has come perilously near to success. Who, if any, will next yield to the temptation and the false promises of grasping leaders no one is wise enough to know. When one or more of the great steel producing countries does yield to the temptation —then will come World War III and horrors vastly worse

than those of World War II. But we need to recognize that the potential power is present in these steel areas, whenever the vicious purpose may arise.

### *United States Iron Ore Resources*

The vast inroads made on the "actual reserves" of the iron ores of Lake Superior are rapidly bringing near the day of their exhaustion. A very clear presentation of this situation was made in 1942 to the War Production Board by E. W. Davis, Director of the Minnesota Mines Experiment Station. His figures of reserves are well authenticated and are used here.

The total iron ore reserves—"actual reserves"—in the Lake Superior District at the end of 1941 were 1,292 million tons, of which 1,077 million tons were in the Mesabi Range and 215 million tons in the five other ranges. Of Mesabi Range reserves one third must be mined underground, one half was open pit direct shipping ore and one sixth was ore that must be concentrated.

The 215 million tons in the other Lake Superior iron ranges included 11 million tons of open pit ore, 17 million tons of open pit concentrating ore and 187 million tons of ore that must be mined underground. This 187 million plus the 376 million tons of underground ore on the Mesabi range gave total reserves, for underground mining, of 563 million tons. This is a lot of ore. It looks large enough to last a long time. But in a normal year, with Lake Superior shipping 45 million tons, the underground mines shipped about 15 million. At this normal rate the underground ore reserves would last nearly 38 years. In the urgent necessity of present war need the underground mines by hard work got their production up to about 20 million tons a year in 1943. At this rate they would last 28 years.

Such figures don't tell the whole truth. No ore body is ever mined out at an *average* rate. It is like an oil well

somewhat. When it first gets into full production it produces at a maximum rate. When it has been mostly mined out its rate drops off—there is no longer room in it for so many men to work. The last years are what miners call "scramming," a very good word to describe the scramble for the last small tonnage on the fringes of the original ore body.

So the underground ore of Lake Superior wont be exhausted in 28 or 38 years simply for the reason that it wont be produced at the rate of 20 million or 15 million tons a year. It will taper off so that 28 years from now we may be producing—if World War III demands the maximum production at that time—possibly as much as 8 to 12 million tons a year from our underground Lake Superior mines. In 38 years, instead of being exhausted, they will be producing perhaps 6 to 10 million tons a year if that is the time World War III demands all that can be produced. But the production will be at a rapidly diminishing rate.

We have looked first at the picture of the underground mines, because that is the longest lived part of our Lake Superior ore picture.

Now let's consider the open pit ore. Of this kind of ore the total reserve in the Lake Superior ranges amounts to 569 million tons of direct shipping ore and 160 million tons that are suitable for present methods of concentrating, a total of 729 million tons of open pit ore. (In this we can forget the small tonnage of underground ore that is concentrated.) Of this 729 millions, 700 millions, are on the Mesabi Range. How long will this last? At present war rates of about 70 million tons a year from the Mesabi range those 700 million will last 10 years. At a more normal rate of 30 million tons a year they will last 23 years.

But again these *average* rates don't give the real picture. Instead of being mined out in 10 or 23 years—*before* the beginning of the World War III the Junker generals were

talking so openly about before Hitler "hushed" them—these open pit ores will taper off in similar fashion to the underground mines. The tapering off process will be much more abrupt in the open pit mines however.

Your attention should be called to the fact that these reserve tonnages were what existed at the end of 1941. Three years of heavy production have taken their toll already. At the end of 1944 these precious reserves are not the 1,292 million tons we have been talking about. There are perhaps 1,025 million tons total left in the Lake Superior district.

Mr. Banker: If that were the whole picture for iron ore in the United States it would be decidedly disheartening both to the stockholders of our company, and to all its employees. But I can't believe that it is so black as that. Haven't we reserves elsewhere that we can draw on, can't the Birmingham district step into the breach, aren't there greater tonnages to be gotten from the various western districts, or from the eastern magnetites, to take the place of Lake Superior ores? What about that great tonnage of "potential reserves" you gave us in that long table, didn't you tell us that the United States had 39.1% of the world's total potential reserves?

Mr. Hotchkiss: Perhaps I can answer your questions Yankee fashion, by asking another. How much ore does your steel plant, which is in the Pittsburgh district, ship in from Birmingham?

Mr. Banker: I don't believe we ship in any. The matter has never come up in a directors meeting and I've never looked into it, but I suppose the Lake Superior ore is better and cheaper.

Mr. Hotchkiss: That is much of the answer. It is better and cheaper in Pittsburgh. The Alabama ore has "actual" reserves estimated to be a little larger in *ore* tons than those of Lake Superior were at the end of 1941. But it contains

35% iron. In every ton you would get only 780 pounds of metal content, but you would pay for mining, and transporting a ton. In the average ton of Lake Superior ore you get 1160 pounds of metal content—about 50% more in a ton. So it is better, and it also is cheaper. Your plant couldn't make steel from Alabama ore as cheaply as you do from Lake Superior ore.

But there is another part to the answer. The vast steel production of the United States has grown from infancy to gianthood on a diet of rich clean Lake Superior ore. Its blast furnaces and steel mills are designed and built to use that ore. Its skilled men know in superb fashion how to make good steel from that ore. To start to feed Alabama ore to those furnaces in place of their past diet would result in a sorry mess. Furnaces, steel plants, and skilled operators would rebel. Results would be quite similar to those obtained from a group of skilled American miners transported to Russia. They were enthusiastic converts to bolshevik theory and enlisted to go to Russia and join their communist brethren in making the great new idea go. When they got to Russia and were expected to eat the black bread and soup of the Russian friends they promptly rebelled. They got out of Russia as fast as they dared.

Our great steel production is an industry specially developed to fit the conditions it has had to meet in the past. It knows how to meet the difficulties encountered in handling its familiar raw materials. If you were to change those raw materials you would have to develop a whole new group of skills to meet the unfamiliar troubles. This fitness of the industry is the other part of the answer to your question.

Yes, it would cost this country more in both money and trouble to make its steel from Birmingham ores. It could be done, however, for the period those ore supplies would last. Almost certainly it would result in a great increase in steel making in the Birmingham district and a gradual

diminution of steel making in the present areas depending on Lake Superior ores.

Even a gradual transition of this kind would be an economic catastrophe, stretched out over a score of years, for the districts supplied by Lake ores. To think of the furnaces and steel works, the stores and homes, the schools and churches, and all the other property whose values would gradually fade away. True, they would be replaced elsewhere, but the economic loss would be great in the present steel areas using Lake ores.

The same could be said of the Newfoundland or Cuban ores, as of those in Alabama, which are the next largest North American "actual" reserves. The reserves we are using in only small tonnage or not at all, have disabilities of one kind or another, they are low grade, they contain undesirable impurities, they are in small or thin deposits, or they are far from markets. All these disabilities spell one of two things—too expensive steel or poor quality steel would result from their use.

But sooner or later we must adjust our economy to one or both of these two things. As our present cheap high quality ores are exhausted we certainly will have to pay more for our steel. How much more it is beyond my ability as a prophet to state. But if we are willing to pay enough we can continue for a long time to get high quality ores from Lake Superior. I will hazard a guess that this will prove to be the cheapest solution of the problem for our steel industry, and by far the cheapest and best for all the owners of property of all kinds and all the labor in our present steel industry using Lake Superior ores.

Our present "actual" reserves in the Lake Superior ranges are rich spots in great rock formations, like "raisins in a cake." The "raisins" make the billion tons of "actual" reserves. The rest of the cake comprises several hundred billions of tons of those unusual rock beds that we call

"iron formation": The richer parts of these formations that carry 35% of iron, or better, are what make up most of the 23 billions of metal in "potential" reserves given in the table.

The greater part of these iron formations will contain 20 to 30% iron, or 30% to 45% iron oxide. The other 70% to 55% is chiefly silica, mostly free silica, but in some small part chemically combined with iron, lime, magnesia, alumina and minor constituents. Where the iron oxide is magnetic present developed processes can be used to concentrate it at a cost from the finely pulverized rock. Of this kind of material there are about 10 billion tons on the east end of the Mesabi that contain 25 to 30% iron—as rich as some of the magnetite ores now being commercially concentrated in the eastern area in New York.

Where the iron in the iron formation rock is not magnetic the process of concentration is not well worked out, except for very particular special phases of the iron formation of limited extent. With sufficient careful research it is highly probable that ways can be found to concentrate the non-magnetic parts of the iron formation. Whether this can be done as cheaply as by the magnetic process remains to be seen, and one is of course warranted in skepticism until it is accomplished. My skepticism is not of the sort that would say it is not worth trying. In fact I plead guilty to trying when I was at the Michigan College of Mining and Technology and of being encouraged to believe that further trials are well worth making. I believe strongly that ways will be found to utilize much of those hundreds of billions of tons of "potential" iron ore reserves that lie in the Lake Superior ranges, and almost certainly make by far the greatest quantity of "maybe" available iron in the world. My only question is whether the ways to utilize these will be found in time to prevent disastrous failure of our ore supply.

My conviction is that the Lake Superior district can and must be made to continue to supply adequate raw material for our steel industry. It will require strenuous efforts, both in research, and in the construction of the vast plants required if this is to be done in time to meet the urgent necessity.

I shall have more to say in a later session of our forum as to the inability of such an ore industry to do what our present open pit mines have done to meet a war emergency.

Mr. Banker: Thank you for giving me more hope than I had early in this discussion. But now I want to ask whether this research you spoke of is being adequately done.

Mr. Hotchkiss: The state of Minnesota has had a very well operated Mines Experiment Station which is doing excellent work on the Minnesota iron formations. Some private companies have a joint research laboratory and a number of individuals have been interested in this research. But I think I should answer your question by stating that not enough research is being done until suitable processes are actually turning out satisfactory iron ore manufactured from iron formation rock.

When this stage is reached—note I used "when" instead of "if"—and iron ore factories are turning out our ore supply, it will be possible to vary the product to suit various needs. We will have ores made according to specifications to fit special purposes, just as now the automobile industry demands steel made on specifications to fit the particular function they fill in your car. They want one kind for body plates, another for shafts, another for axles, and still different kinds for springs. Ores best fitted to make these steels can "then" be supplied by the iron ore factories. Before "then" many millions of dollars will have been spent on research and construction. Some of those millions will have been lost, as in all great new ventures, but out of those losses and mistakes will come, *I hope*, a long, certain, sure

future of our ore supply, which at present shows so unhappily short a life.

### *The World's Aluminum Ores*

Bauxite is the only ore of aluminum at present used. This ore is the oxide, and is usually used ony when the ore contains at least 50% of oxide. It takes roughly 4 tons of ore to make one of metal. This oxide is the product of tropical weathering of various rocks. The United States supply has mainly come from Surinam—Dutch Guiana. Recent finds in Jamaica and Haiti have greatly increased the volume of our available reserves. Other discoveries of large deposits will doubtless be found in tropical and subtropical regions. The probable supply is large and will run into many hundreds of millions of tons.

To last for a hundred years at present rates of war time world consumption would require approximately 800 million tons of bauxite. At half that rate, which is probably a low average for the next century, we would require 400 million tons. These figures give about as close estimates of needs as are possible at present. We can probably count on enough bauxite for a century.

Aluminum occurs most abundantly in combination with silica in clays, shales and many other common abundant rocks. Much research has been done to find cheap methods of getting the metal from such sources, but none has yet been found so cheap as present methods of getting the metal from the oxide, bauxite. Whenever we have to use these sources we can do so at somewhat increased cost, and then our aluminum supply will be inexhaustible.

### *The World's Copper*

For the XVIth International Geologic Congress in 1935 there was prepared a statement of the published ore reserves of the large copper companies only. According to this

there were at that time known in the world bodies of ore of grades commercially workable with a total copper metal content of 76 million tons, divided between the continents as shown in the table.

We are ready for your chart of copper reserves, boys.

Dick: Here is the chart.

TABLE XXX

Copper Reserves of the World's Great Mines in 1935

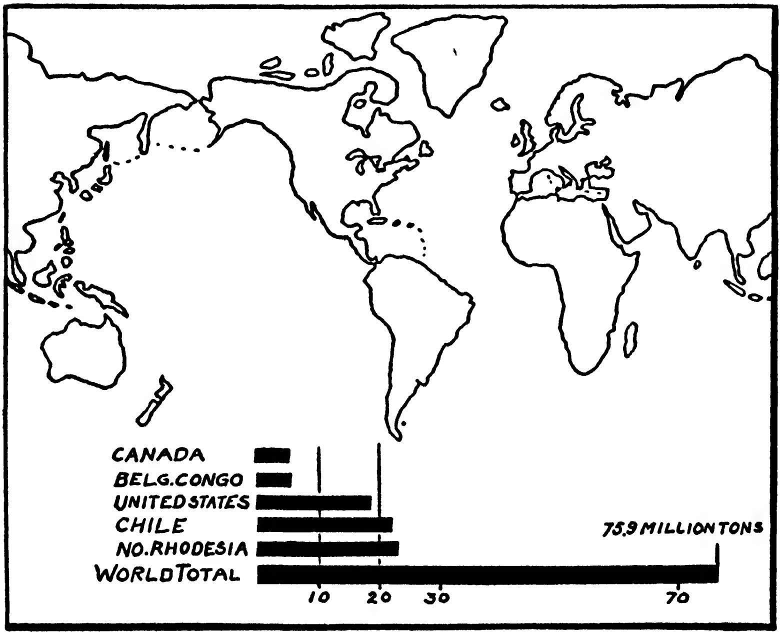
(In short tons of metal content)

| | | *Percentage* |
|---|---|---|
| North America | | |
| Canada | 5,451,400 | 7.4 |
| United States (includes one Mexican and one Cuban mine) | 18,480,600 | 25.0 |
| Total | 23,931,000 | 32.4 |
| South America | | |
| Chile | 21,600,400 | 29.2 |
| Africa | | |
| Belgian Congo | 5,512,000 | 7.46 |
| Northern Rhodesia | 22,569,300 | 30.5 |
| Transvaal | 34,600 | 0.05 |
| Total | 28,115,900 | 38.01 |
| Others | | |
| Sweden | 132,000 | 0.18 |
| India | 22,500 | 0.03 |
| Australia | 131,500 | 0.18 |
| Total | 296,000 | .39 |
| World Total | 75,934,300 | 100.00 |

The foregoing figures are probably more reliable in their percentage distribution of the worlds total copper than they are as to the total tonnage. Three continents have roughly one third each, Africa most, north America second and South America third.

These estimates would undoubtedly be different if we had up to date facts. An estimate for the United States made in

1939 as a National Research Project of the W.P.A. gives a reserve of 36 million tons of copper metal in known ores workable within price ranges of recent years. This is nearly 50% more than the reserves given in the table. Other reserves in the table could doubtless be increased




*World Copper Reserves.*

by substantial amounts. If ores of as low grade as are mined in the United States could be profitably mined in other parts of the world, especially in Africa (which is handicapped by long distances from markets, from sources of supplies, by labor shortage and other difficulties) the worlds reserves could be multiplied.

If we assume an average need of 3 million tons of copper per year by the industries of the world in the next gener-

ations it is probable that reserves are available for a period of 50 to 100 years in ores of present grade or nearly so. Others may be discovered, possibly already have been in worth while quantities in that great mineral storehouse about which we have been permitted to know very little since World War I—Siberia.

By exploitation of known ore bodies in the United States, Chile, Africa and elsewhere which are too low grade to be profitably exploited now, the worlds supply can be greatly increased. Also there is the possibility of new discoveries of ore of present exploitable grades. By these two methods we can feel reasonably assured of a supply for a century. Perhaps then we will have so great a supply above ground that our need for new metal will not be so great as it is now.

### *World Resources of Other Metals*

The other metals we use in considerable tonnages are lead, zinc, maganese, tin, nickel, tungsten, chrome, molybdenum, vanadium and mercury. Outside of a very few large deposits of these metals our supplies come from many small ore bodies, too small, too scattered, and too little developed to make it possible to make even a rough guess as to the future. These supplies are vital, we don't know how to get along without every one of them. The only dependable feature of the supply for the years ahead is that compared to coal, iron and copper the required amounts are moderate enough so that we can afford to pay a higher price, when it is necessary to get them. If we had to pay twice as much for our steel it would be a severe handicap. It would almost certainly mean that we would get along with appreciably less, and would substitute other metals, concrete, or wood or plastics, wherever feasible.

For vanadium, molybdenum, tungsten, manganese, tin and mercury we could pay double for the relatively small

amounts we require without reducing our use very greatly. A greater price would produce a greater supply for many of them for a time, and would stimulate search for other ore bodies in new regions. But eventually even these metals of relatively small use will be used up. How long they will last no one can say because no one knows how much is hidden awaiting future discovery.

Lead and zinc are intermediate between copper and the metals above mentioned. They are used in much greater tonnage than the list in the last paragraph. At times the supply is scant and at times plentiful. When the price is up the search for new deposits is stimulated, and we have had success in finding them so far. How long we can keep this up no one knows. If we are in a period of low supply at the time of World War III, whenever that may be, it could be exceedingly embarrassing. It is a bit difficult to make satisfactory rifle and machine gun ammunition without plenty of lead. No other common metal is heavy enough to take its place. Zinc and copper are necessary for the brass cartridges also. So an adequate supply of lead and zinc is a wartime necessity. Some European nations, I am told, have long recognized this and have kept war stocks available to which they added energetically when war clouds darkened.

The reserves of nickel ore are fairly large, and new large deposits have been found in Finland and Brazil. There is a good possibility that still others will be found. Nickel we know in sufficient quantities so that we need not fear a shortage for approximately a century.

Lead and zinc and the others under this heading we do not know in supplies to serve us for so long a time. We would be hard pressed for most of them in 25 or 30 years if no new discoveries are made. Only in this hope can we look forward to a long supply. It's a case of maybe or maybe not. Let us hope that the typesetter who is setting

up the record of the future leaves out the "not," and then let us use what supplies we have with appropriate wisdom.

For some of them, such as manganese, we may see perhaps as much as a hundred years supply at present consumption rates but for most of them the visible supply will last a much shorter time.

Among the lesser minerals of non-metallic kind such as sulphur, graphite, mica, cryolite and fluorspar, we know little about reserves, except of sulphur. There is a known supply of sulphur for perhaps a generation, and there are possibilities for other large discoveries in the Gulf region. It is likely, however, that we are skimming the cream of this resource, and may later have to depend on pyrites for our sulphuric acid. This will probably cost somewhat more but the supply will last at least as long as our sulphur has.

Fluorspar and cryolite are not found in ore bodies that permit us to see more than a very few years into the future.

### *The World's Petroleum Reserves*

With this commodity we come to one that has the greatest dollar and use values of any mineral resource. It is also one having in known measurable reserves, a supply sufficient for a period shorter than any other great mineral resource.

Reserves of petroleum in the United States are estimated by the American Petroleum Institute as of Jan. 1, 1944 to be 28,098,467,000 barrels of 42 gallons—28 billion barrels. Compared to the iron ore reserves these are what should be called "actual reserves." They include the estimates of oil in known fields that will be recovered by present known methods. They do not include any estimate of oil that remains to be discovered in presently unknown oil fields.

At pre-war production rates of 1.25 billion barrels per year they would supply our needs for 22 years. At war production rates of 1.5 billion barrels they would supply us for nearly 19 years. But here also the averages do not

tell the story. These reserves cannot be drawn up at will. We can take the oil only so rapidly as natural conditions permit it to flow to the wells through the porous rocks in which it lies. From these presently known reserves we will undoubtedly be pumping oil long after the 19 or 22 years is past, because we can't take the 1.25 or 1.5 billion barrels a year each year for those periods.

Our future use of petroleum depends in large degree on future discoveries in this country and on increasingly large imports from foreign sources.

"Actual" reserves of oil outside the United States are not known with anything like the definiteness of our United States reserves. Neither is there as good a basis for estimating the future potentialities. The oil industry of the rest of the world is not so well developed as is ours.

Estimates of *potential* oil reserves of the world, and of our own as well, vary widely, according to the optimism of the estimator. The extremes would be typified on the low side by the most cautious who would perhaps be willing to increase the 22 year duration of our United States supply by 50%. On the high side there is the extreme optimist who assures us that oil is being formed in the rocks as fast as we use it, with the inference that our oil supply is inexhaustible. We will have to admit that either *may* be right. In a resource so deeply hidden in the earth as oil we know that our knowledge is necessarily scant at best. We can't tell whether it is there without drilling expensive wells, and when we find it, many more wells must be drilled before we can tell much about the quantity, so what can we know about an undrilled region. We can say that oil is possible or even probable in certain areas, but any guess as to quantity is what one oil geologist friend of mine denotes "finding oil with a lead pencil." I wish I could see reason to think our oil supply is inexhaustible, but all the geologic reasons I know point definitely to the contrary. In my judgment we will be

very wise to assure ourselves of adequate sources of foreign oil to supplement our diminishing domestic supply.

There are undoubtedly large reserves of oil in the world. It is quite certain that there is enough to keep us travelling in cars for nearly a generation. It is *probable* that there is enough for a longer time, perhaps two generations. It is *possible*, but very doubtful, that there may be enough for as much as a century or two. But beyond that the probability becomes very strong that we may have to depend on the more expensive substitutes such as shale oil, or synthetic oil made from coal. As the cost of our oil supply goes up our use will go down. Instead of operating an automobile on the average for each four persons as we do now, perhaps half of our drivers will be unable to afford the higher cost of operation and we will have one for every eight of our population—or some greater or less reduction—but reduction will come with increased cost.

For two most interesting discussions of the petroleum situation I would refer you to *Oil in the Earth* University of Kansas Press, 1943 by Wallace Pratt, Vice President of Standard Oil of New Jersey, and *Peace, Plenty, and Petroleum* by B. T. Brooks, a petroleum chemist with world wide experience in oil refining.

### *Distribution of Mineral Reserves*

The distribution of these important mineral reserves among the leading countries of the world is of vital importance for the future. No country is self sufficient. All depend for some important mineral resources on other countries and international trade. In case of war the nations that control the seas are the only ones that can secure what they need. If other nations have not laid up sufficient stocks before war started their industries will suffer, and their capacity to carry on war will be seriously crippled.

Germany's shortage of petroleum is probably the most important factor in her downfall. Because of that her Luftwaffe and her motor transport cannot meet the demands for their services. Shortages of chrome, tungsten, manganese, high grade iron ore, mica, quartz crystal, tin and vanadium are all important, and prevent her from producing adequate equipment once her accumulated stocks are exhausted. Within her own boundaries she has in abundance only coal, low grade iron ore, potash, and magnesite. She has some copper, but not sufficient to supply peacetime needs. Also in less than peacetime needs she has a partial supply of bauxite, lead, nickel, phosphates, and zinc. From occupied countries she supplemented sufficiently her supply of bauxite, potash and zinc. From occupied countries, her allies, and others adjacent she got adequate or nearly adequate supplies of iron ore, copper, lead, zinc, mercury, and sulphur, and supplemented her oil supply insufficiently. From Nikopol in occupied Russia she undoubtedly took much manganese while it was in her possession.

This gives a picture of Germany's dependence on outside sources of supply.

Japan had within her boundaries and Manchukuo a sufficient supply of only magnesite and sulphur. In insufficient supply for peacetime needs she had chromite, coal, copper, iron ore, manganese, mica, nickel, nitrates, petroleum, phosphates, tin, tungsten and zinc. Japan could get a sufficient oil supply only by capturing the oil fields of the East Indies. She was dependent on outside sources for sulphur potash, molybdenum, nickel, manganese, vanadium, tin, chromium, antimony, lead, zinc, mica and graphite.

Russia has ample supplies of asbestos, magnesite, manganese, petroleum, platinum, coal, and iron ore. She has supplies, sufficient for her needs, of chromite, graphite, phosphates and potash. She is dependent on others for

part of her supply of antimony, bauxite, copper, lead, mercury and sulphur. She lacks almost entirely supplies of industrial diamonds, mica, nickel, natural nitrates, quartz crystal, tin, tungsten, and vanadium.

The United States is possessed of abundance of only six mineral resources, coal, copper, iron ore, petroleum, phosphates, and sulphur, but five of the six are the most important necessities. She has, in less abundance in proportion to her needs lead, magnesite, potash, vanadium, and zinc. The United States is partly dependent on outside sources for antimony, bauxite, chrome, graphite, mercury, and tungsten. She is completely dependent, or largely so, on outside sources for asbestos, industrial diamonds, manganese, mica, nickel, natural nitrates, platinum, quartz crystal, and tin. No other single country has so much of the most important mineral resources within her own boundaries, but there are nine important lesser minerals that we do not have and six in which imports must supply the greater part of our needs.

The British Empire as a whole is the most completely supplied with mineral resources of any political group, but in the British Isles, the industrial center of the Empire, only two mineral resources are present in abundance, coal and low grade iron ore. For all others her dependence lies on control of the seas. She must import her needs from the other parts of the Empire and from outside countries. The Empire as a whole has ample supplies of asbestos, bauxite, chromite, coal, copper, industrial diamonds, graphite, iron ore, lead, manganese, mica, nickel, platinum, tin, tungsten, vanadium, and zinc. It has phosphates in fair supply, and magnesite in insufficient supply. The list of minerals for which it must depend on sources outside the Empire includes six minor ones, antimony, mercury, natural nitrates, potash, quartz crystal and sulphur. In addition to the six minor ones the list includes however the most

important of all, petroleum. It will be interesting to watch the outcome of this war and see if Britain does not acquire an even more firm hold on much of the large oil reserves east of the Mediterranean. British and American interests before the war held 95% control of the production, British interests 80%, United States interests 15% and others only 5%.

These last statements give some indication of how all industrial nations are dependent on free access to supplies of important mineral resources. No nation can ever hope to own outright all the mineral supplies it may need. Every nation must depend on others for supplies of some of the minerals vital for its industrial needs.

# CHAPTER 7

# The Peace Future of Mineral Resources

MR. LAWYER: We have a generalized picture of the amounts of the various mineral resources the countries of the world produce and use and how they are used. We have as adequate a general picture of the world's reserves of these minerals as it is possible to have with our present incomplete knowledge. If we succeed, as we hope, in winning this war and in making a peace that will last for a century or more what are the developments we may look forward to as possible? We read occasionally of such things as plastics and how they will be substituted for metal in many of our present uses, or how aluminum may replace other metals in important tonnages. We read of the possibility of alcohol from vegetable sources replacing gasoline in our automobiles, thus making us independent of gasoline from the earth's stores that we are using up so rapidly now. I think we could spend a profitable session of this forum in discussing these and similar things.

Mr. Hotchkiss: Such a discussion should be of interest I agree, but how profitable will depend upon how good we are as prophets. I for one must truthfully disclaim any prophetic ability. As Will Rogers used to say "I only know what I read in the papers." But we can start out with the things that seem most likely to develop and go as far as we like after that in speculating on possibilities. But the outcome in all these things depends so completely on unknown and largely unpredictable developments in science and technology that we must not forget for an instant that

science and invention promise much more for the future than they have given us up to the present. There are *possibilities* ahead of us which we cannot by any chance foresee that may effect most important changes.

For example let us suppose an almost impossible thing and speculate a moment on its effects. Suppose some scientist were to discover a cheap simple way of counteracting the force of gravity. With this cheap simple device in our pocket we could turn it on and rise in the air as far as we pleased. With a small outboard motor and a rudder we could soar about like birds. Instead of heavy foundations for our great buildings to distribute their enormous weight on the soil we would only need under them a cheap simple gravity counteractor. With this we could float our heaviest buildings on air if we wanted to. Our railroads would find themselves without heavy freight—for all our heavy articles would be shielded from gravity and would become light. All freight would be wafted into the air and towed by air to its destination with only air friction to overcome. We would need no steel for rails. We would need no cumbersome heavy machinery of steel and cast iron except for rigidity and strength needs. Aluminum and magnesium would lose their virtue of relative lightness.

We could go on with this fanciful picture as far as we like and construct a whole new way of carrying on the worlds business of producing, distributing, and selling the things that people need to live. But this gravity counteracting device is not one to worry about. It is an exceedingly remote possibility. Nor is any other scientific discovery likely that will completely revolutionize our way of living and the uses we make of mineral resources. Whatever changes may come are in all human probability going to be evolutionary in character. So we are safe to confine our thoughts to evolutionary developments.

A good group to start with is what we have called the

inexhaustible resources. Neglecting air and water and coming to the mineral resources we find these chiefly used as construction materials. We build our homes and schools and churches from these or from wood. We build our roads and bridges and dams from stone, gravel, sand and cement. The developments we may foresee in these relate chiefly to cheaper and more efficient methods of preparing, handling, and using. We have made relatively little progress in methods of building homes and other structures for human occupancy. They are far from efficient in keeping out cold and noise, and for keeping heat in or out according to the needs of the season. How these things will be done I do not pretend to say. I am merely indicating the fact that there is much present inefficiency, which I am confident will be improved.

This will come gradually. Some contractor or architect or engineer or workman will find a way he can do a job better for the same cost as his competitor, or do an equally good job for lower cost. After he has done this for some time at a good profit others will adopt his methods. Before long the improved cheaper method will become general practice. Then some other man will find another way to do something else better and that in turn will be adopted. That is the way we have progressed in the past and will surely be the way we will progress in the future unless some conditions arise to deprive us of initiative and independence of action. And then we will no longer progress.

When iron and other metals become sufficiently costly in an economic sense—take too much of our time and energy to produce them from less adequate sources than we have now—we may find it less laborious to extend our use of the inexhaustible resources to save part of the needed metals.

If, in the future, iron and steel are more difficult to get, we may supplant them in many further uses with aluminum and magnesium, the only two inexhaustible metals. Many

small articles would be just as satisfactory if made from aluminum or magnesium as from steel, copper, brass or zinc. As I look about me I see a floor lamp, and other lamps, a smoking stand, knobs, hinges, piano pedals, book ends, hooks, curtain rods and other items, all of iron or brass, that would serve me just as well if they were of aluminum or magnesium alloy. So the only factor, other than that of custom, what I consider suitable or of good appearance, is that of cost. If you look about you in your home you also can see many metal articles that might just as well be one metal or another so far as your actual needs require.

So we may expect to see a wider use of the inexhaustible metals in the future, to partly replace the present uses of exhaustible metals.

As to plastics replacing metals in any considerable degree my guess would be that it is not very likely. We will greatly develop plastics and they will replace many minor uses of metals in small articles, where metal has been a convenience rather than a necessity—cheaper and simpler to make, say, than cabinet work. There is a vast field of usefulness for plastics, and their use will help to conserve our metals, but they are unlikely to replace them in any large tonnage way.

It is chiefly with the exhaustible resources that our interests are concerned. They are the ones that have contributed most to the upbuilding of our welfare in the industrial revolution, and which we have used in such staggeringly increased quantities in the last generation. These are our energy resources and the metals chiefly.

We may with profit first consider our energy resources. We have seen on page 112 that these are in greatest part coal, petroleum, natural gas, and water power. Water power is the only one of these that perhaps could be ruled out here on the score that it is inexhaustible so long as the rain falls and streams run that can be dammed to develop

the power. But water power is most decidedly exhaustible in that there is not enough of it to supply our power needs. We can exhaust the supply by developing and using all there is.

Approximately a third of the estimated total water power in the United States has been developed. The total energy available for our use in 1940 is given on page 112. Of this the water power was only about 3.5 percent. So if all our water power is developed it will amount to only about 10 percent of the 1940 amount of power available from all sources. It must be remembered that the part already developed is the part which could be developed with the least cost. The other two thirds will cost increasingly greater amounts per horsepower.

Notwithstanding this we can expect to see more water power developed, particularly where power, irrigation, and flood control needs are served by the same dams. Probably the next century will not see the development of more than another third, or thereabouts, of our total potential United States waterpower.

The economics of water power development is a contest in cost between it and the cost of steam power developed from coal, oil or gas at any given location. Niagara Falls is a relatively cheaply developed source of water power. Yet one of the country's leading water power engineers stated over thirty years ago that if Niagara Falls were located at St. Louis it would cost more to harness its power than it would to produce that power in steam plants from the cheap, close by, Illinois coal.

The world's total water power, developed and potential, has been estimated to be about 455 million horse power. Of this total North America has 66 million, Europe 58 million, South America 54 million, Asia 69 million, Oceania 17 million, and Africa 191 million. This whole amount, if located in the United States and all developed, would be

about equal to the total energy content of our total production in 1940 of coal, petroleum, natural gas and developed water power.

The potential water power of Africa, over 40 percent of the world's total, will be long unused. Power is of use in large quantities only where manufacturing populations exist to use it, or when it can be transported to manufacturing centers. African water power has prospect of a using population relatively limited in numbers. There is no way in which its power can be transported economically to Europe. So African water power, in the large, is about as useful as a deposit of high grade coal at the South Pole. As population there increases some development of water power will come.

Water power in Europe and Asia will be developed much more extensively than African water power because there are populations to use it. Europe's total potential power is about as fully developed as that in the United States or perhaps somewhat more, but Asiatic water power resources are relatively little developed. South American water power also is relatively little developed—only about 2 percent is harnessed—so there is likely to be much development there, particularly as South America is practically devoid of coal resources. Developments of oil fields will tend to delay the development of water power.

Our principal power sources are coal, petroleum, and natural gas. Of coal we have plenty. Developments the United States will see in the future will consist largely in important improvements in the efficiency of its use. While our use of coal in general is of the order of 6 percent efficient, we know how to use it with 35 percent efficiency and are now doing it in great central stations generating electricity. This makes a wide range for the play of engineering talent to bring our average up toward our present maximum. The increasing cost of producing coal furnishes a powerful spur to con-

tinuing this increase in efficiency by making the savings to be made greater for each ton of coal saved.

In addition to the savings to be made on the basis of our present knowledge there are potentialities of still greater advances in efficiency from future developments of science. We have no present cheap efficient way of storing power. The storage battery in your automobile is the best we have, but it has no place in a storehouse of large amounts of power. If science can develop some efficient means the excess capacity of our power plants necessary to meet peak demands could be used to generate power and store it in off peak hours and seasons, and so produce power more cheaply.

Also there is the unknown possibility that some way may be found by science to transform the heat of burning coal into electricity directly and cheaply, instead of by the present method of the steam engine. If this could be done the present limitation of 35 percent efficiency in our best steam plants might be by-passed and much higher percentage efficiencies attained. If and when this is done and the heat of burning coal or oil is even 50% directly transformable into electric energy just imagine the multiplicity of beneficial effects that would follow.

If it could be done in small power plants that would fit your automobile imagine the comfort and flexibility of a car with no reciprocating engine and no vibrations but with a small electric motor on each wheel, driving your car 100 miles with a gallon of gas, or eleven pounds of coal. You could put 15 gallons of gas or 120 pounds of coal aboard and make a 1500 mile trip without refueling. Your oil consumption would be only that necessary to oil your electric motors and the wheels and steering gear.

With such efficient fuel use air planes would be much cheaper to operate, and engine vibration and exhaust noises would be eliminated. Electric locomotives would be simpler

and cheaper than today by far and the present relatively inefficient steam locomotives would be done away with.

Of petroleum and natural gas supplies even most of the optimists would agree that we have too little to be sure of a long future. But we will have enough for a generation and more at present consumption rates. Developments here will not only be in the line of increased efficiency of use as fuel, but even more in the use of petroleum as a supply for chemical manufacture. Synthetic rubber and alcohol are only a beginning of what the future holds in this field. You asked about vegetable alcohol replacing gasoline in our cars. As a matter of fact the replacement would be cheaper to make the other way—to replace grain alcohol with alcohol made from petroleum. When we use alcohol in our cars it will be because all other sources of motor fuel are exhausted.

The most important development we will see in our time in petroleum will be that progressively more of our supply will come from foreign sources. Pipe lines that now transport Gulf coast oil to the Great Lakes region will be used more and more to transport foreign oil to the Great Lakes.

But while we are dwelling on possibilities in the field of power resources we must not neglect the greatest of all—the power we get from the sun. This is enormous and if it is ever cheaply harnessed our power supply will be abundant beyond all possible needs that can be imagined. It has been computed to be the equivalent, in the growing season in our mid-latitudes, of the energy in 200 tons of coal per acre. In a years time it would be from fifty to one hundred per cent more. This would transform our barren, uncultivateable, rocky hill sides into sources of all the power we would need. The roof of a 30 x 40 foot house would receive the energy equivalent of 9 to 12 tons of coal in a years time—enough, with the supplementing aid of the back yard, to heat it, air condition it, light it, and provide all the power needed for domestic appliances.

The rotation of the earth combined with the energy of the sun, together give us another vast potential source of energy, the wind. But wind power is erratic and not dependable as a steady source, even more so than sun power which the clouds cut off. Both these sources of energy can be drawn on for effective large supply for industrial uses only after some cheap effective way is found to store energy in large quantities. But all these things are well within the limits of scientific possibilities. Whether they will happen or not no one can say, and if they are to happen no one can now tell the time of their occurrence.

Other sources of power that you see mentioned, such as atomic energy, may be written off at present as not much more than vain imaginings, not impossible perhaps but exceedingly improbable.

Of the future of the metals that of iron is of the greatest significance to us in the United States. We can dismiss copper, lead and zinc with the statement that the world supply will be adequate from known sources of copper for probably a century, and for lead and zinc a shorter period with possibilities of other discoveries. Their uses are well developed, and barring revolutionary scientific discoveries, will continue to be in kind nearly what they are. Shortages will encourage greater uses of the inexhaustible metals, aluminum and magnesium, and plastics, and so automatically limit their uses to those needs least readily supplied by substitution, thus conserving supply.

In iron however the fairly rapid exhaustion of the higher grade ores from present sources will cause one or both of two changes in our methods of supplying the needs for iron ore in the United States; 1) We will use more foreign high grade ores, or 2) We will depend more upon "manufactured" iron ore—made by concentrating ores with lesser iron content into ores rich enough to use in the blast furnaces. Transportation costs of foreign ores will be large enough to

offset in some measure the cost of concentrating low grade ores in the United States. So far as the use of foreign ores increases it will encourage the shift of some of our steel industry to coastal locations, or to places near the coast where coal and iron ore transportation costs are more nearly in balance than they would be in present interior steel plants. But it is my judgment that the greater part of our iron ore will in the future be supplied by concentrating plants in the Lake Superior district.

But we will probably also see in the next hundred years some shift of our sources of high grade ore to over-seas regions and some consequent shift of the geography of our steel industry.

Foreign steel centers at present depend more largely than we do on foreign ores. England's native ores and those of Germany are very low grade and so they ship in ores from Sweden, Spain, Algeria, and other African sources. Brazil ores will undoubtedly go both to Europe and the United States and, because of their high grade and vast quantity, will play a large part in the overseas iron ore trade in the next generation.

France with its vast quantity will be the main supply of western European iron industries for several generations.

The great steel producing centers of the world will continue to be the United States and western Europe because they have the great coal supplies and can supply their main needs of ore from nearby sources.

The steel production of Russia, India, and China will undoubtedly increase greatly, in the order named. Russia has large supplies of both coal and ore as has India. China's ore supply is much smaller but she can draw additional ore from Pacific sources not too far away, and China has much coal.

The rate at which steel production in these three areas will increase will depend on the rapidity with which these

regions increase their demands, the rate at which living standards approach those of the United States and western Europe. The progress made by Russia in the last 20 years is an indication of what will probably happen in India and China in the next forty or fifty years of peace. We hope that India and China will not have the spur that Russia has had in the last 20 years to prepare as rapidly as possible for a great war. So their development will probably take the slower rate which purely business reasons will necessitate. If a nation is hurriedly preparing for war haste is worth while at a cost greatly in excess of ordinary profit considerations.

In the next generations the world is going to have abundant use for much larger production of steel than in the past. It is to be hoped, therefore, that some way may be found in settling peace terms to properly circumscribe the aggressor nations, and to punish them impressively, without denying the world the use of their steel production. But more will be said about this later.

The preceding statements rest on the tacit assumption that all mineral resources are going to be allowed to flow freely where needs demand. In the Atlantic Charter, in August 1941, the President and the Prime Minister included as paragraph 4 the following: "They will endeavor with due respect to their existing obligations, to further the enjoyment by all States, great or small, victor or vanquished, of access, on equal terms, to the trade and to the raw materials of the world which are needed for their economic prosperity."

In the light of the false propaganda over the years by Germany that she was a "have not" nation this paragraph was read by most people, I believe, as *assuring* Germany access to the world's resources on the same terms as all other nations, "victors or vanquished." Such assurance was not within the power of the President and the Prime Minister to give. It is not at all certain that Great Britain could compel even Canada to sell nickel to Germany if

Canada was determined not to, and as to compelling any of the South American nations to sell their products to Germany against their will, surely such a guarantee is unthinkable. So paragraph 4 began with the words "They will endeavor, with due respect to their existing obligations, to further" etc. These qualifying words permit the widest range of performance.

As a matter of fact all nations are "have not" nations. No country is sufficient to itself in natural resources. They can all live and prosper in their various ways only as other nations sell them goods that nature never put within their boundaries. If the other nations were to refuse to sell us manganese ore, nickel, tungsten, bauxite, iron ore, copper, tin, antimony, chromium, or mercury they would most seriously cripple *our* industries. And we are as nearly selfsufficient as any of the large powers of the world, and much more so than most. If we were to refuse to buy these materials from them we would most seriously cripple *their* industries. We are a "have not" nation in not having a sufficient supply of each of these in our own borders. The nations who sell us these things are equally "have not" nations in that they have not a consuming market for their product in their own boundaries. This "have not" business works both ways, as witness the August 1944 matter of Argentine beef and the Allied nations.

This brings us to the real difficulties facing, in the further words of that paragraph 4 of the Atlantic Charter, "the enjoyment by all States, great or small, victor or vanquished, of access, on equal terms, to the trade and to the raw materials of the world which are needed for their economic prosperity." These difficulties are likely to be the same old cartels, embargos, tariffs, and governmental restrictions that have hampered the "access, on equal terms to the trade and to the raw materials of the world which are needed for their economic prosperity."

The oil agreement between Britain and the U. S. signed in August 1944 contains a provision for the setting up of an International Petroleum Commission. One of the stated duties of this Commission is "To recommend to both governments broad policies for adopting by operating companies" with regard to production and distribution. This is broad ground for the complete and absolute regulation of world production and trade. Like that so called "best form of government—a benevolent dictatorship," it may work well as long as the dictator *is* benevolent. But it may work otherwise if he is not. And every dictator is always under suspicion just because he is a dictator.

This is the kind of thing that carries seeds of trouble for the future of mineral resource supply and trade, and with that, seeds of jealousy and hatred between nations. If it is the nation that does the act the hatred will be toward that nation. Even with the best of intentions things will be done by such a commission that some nations, rightly or wrongly, will loudly proclaim to be unfair and discriminatory. It would be far more simply dealt with if the trade were handled by business men who could take the blame for claimed unfairness rather than have the national government—the "nation"—in a position where *it* has to take the blame. It would be far better to handle the matter by laws establishing the principles on which American nationals should carry on their part of this world trade in oil, principles which would give the basis for reviewing *their* acts in the courts. This would be less provocative of trouble between nations than would be the case if the same things were done by government bureaus or commissions, whose acts are official acts of the governments involved.

Tariffs, cartels, embargos and other restrictions have done much in the past and can do much in the future to hamper the normal development of trade in mineral resources. If unrestricted the tendency of suppliers is to ship in accord

with demand and to develop new demand wherever it is feasible to do so.

The future of mineral supplies will be best only if fair dealing among the suppliers and the users prevails. Laws and government regulations should be aimed toward assuring this fair dealing. The world will be better off the fewer the laws and regulations that are needed to accomplish the purpose.

## CHAPTER 8

# Mineral Resources and World War III

MAY I state in the first sentence of this chapter that I most deeply hope that the leaders and the people of the world may be blessed with the strong purpose and the requisite wisdom to postpone World War III forever. The state of the world has been admirably expressed by Jan Christian Smuts in his statement on "The Great Lesson of This War."

"The essential oneness of our world is rapidly emerging from the old territorial partitions, and from the point of view of war there is no sacrosanctity in continents, no security in oceans, no safety behind rivers and mountains. The war is burning that fact into our consciousness with a force which no wishful thinking could undo, and calls for a fundamental reconsideration of our international outlook and practice. Such, it appears to me, is the great lesson of this war. That lesson stretches even beyond this war and all war. It goes to the very roots of our human destiny and our existence as man on this globe. In the end, in the last resort, in the final appeal, our human lot is indivisible. On that deepest level, what touches one touches all in this holistic world. Our world has at bottom left no loophole for escape, no hiding place from the storm. When we come to the great issues we find no isolation or neutrality. And war has become the greatest of all issues in our human affairs. Science is rapidly destroying, or at least overriding and overruling, the old boundaries. We are fast becoming neighbors of one another with far-reaching implications for

old concepts and practices like war, race, nationality, and the like. Neighborliness, the "good neighbor," are not only ethical concepts but are rapidly becoming economic, political, and international concepts and standards of human behavior which we violate at our peril. This may be a hard saying, but war is the hardest of all teachers and its nameless sufferings and sacrifices in our generation are at last driving home to us the inner meaning of what religion has always taught us and science is now rediscovering for us."

In considering the role of mineral resources in relation to World War III we can adopt an idealistic approach if we choose, under which we can assume as we did after World War II, that after *this* war mankind will be suddenly converted from the error of warlike ways, that he will see his past mistakes and will guide his future so as to avoid them with perfect wisdom. We hear it frequently stated that human beings should have sense enough to live together as a happy family of nations, and we agree. But we remember the fervor with which we reacted to the slogan in 1917, "a war to ends wars." And we remember our early disillusionment.

So we choose to adopt instead a realistic approach to the matter. We choose to think of the family of nations not as an ideal "happy family" but as a real family. When we survey the makeup of real families we find wide differences, in intelligence, in moral standards (we recall having heard of families with a "black sheep"), in strength both mental and physical, in kindliness of disposition, in reasonableness, in fairness, in energy and ambition, in knowledge, in youthfulness and maturity, in selfishness, in peacefulness, and in all the qualities that make up all human beings. We find the complete gamut of qualities of all kinds from the best to the worst. And I feel quite certain that they will continue to possess all these, both good and bad, for farther into the future than concerns us greatly in thinking of World War III.

In this real family there are times when some of the

younger children get past the stage of sweet reasonableness and father or mother must administer a spanking to put them back on the right track. In some unfortunate families some of the more selfish and headstrong grownups must be punished for misdeeds by being sent to prison, or even to the electric chair. Human society has not got beyond the necessity of thus disciplining recalcitrant individuals with evil propensities. In the real family of nations there is certain to be necessity for similar curbing of those with evil purposes.

We have developed machinery for handling the individual miscreant over the last thousands of years that almost all human beings agree upon as right and proper. We have yet to develop efficacious methods for handling miscreant nations. We have no father or mother to spank the errant child nation, nor have we courts with power to sentence the mature strong miscreant nation to suitable punishment for its crimes. The only method we have is to gang up on him and beat him up if we can. If we cant it's just too bad for us. It will take long generations to reach the stage in international relations that we have recognized for thousands of years as being desirable in individual relations. It will probably take a long series of future wars before nations will recognize the application to them of Franklins statement that they "must hang together or hang separately."

In the sense that I *do not* believe that we as a group of nations have the wisdom and the fairness necessary to do away with war forever in one stroke at the conclusion of World War II, I may fairly be charged with pessimism. Personally I would like to claim that it is intelligent pessimism.

In the sense that I *do* believe that we will eventually develop the necessary machinery for the preservation of world peace out of long trial and repeated failures, I hope my position may be accepted as that of an ultimate optimist.

It is perhaps well to add at this point that I subscribe

most heartily to Walter Lippmann's thesis so clearly presented in *U. S. Foreign Policy*—that our commitments and our abilities to meet them must be carefully kept in balance. Our military strength must be adequate, together with assured support of friendly nations, to meet successfully any responsibility that we accept as ours, or ours and theirs jointly.

I also believe Smuts has stated a great truth in one sentence of the quotation at the beginning of this chapter. "When we come to the great issues we find no isolation or neutrality."

Having given you the fundamental basis of my thinking we are ready to consider World War III, and, from the mineral resources point of view, what we can do to avoid it and how we can best be prepared for it when and if it comes.

Mr. Lawyer: I regret deeply that I must agree with you in your analysis. I wish we both might be more optimistic. In the background of my mind all through this forum I have had the German propaganda after World War I. German leaders convinced her people, and half convinced many others, that the Allies had cheated her out of her rights, that if she had her rights she would own territory furnishing the mineral resources her industries needed. The facts before us in this forum offer conclusive proof that no nation can ever be entirely self-sufficient in mineral resources. The Creator distributed them otherwise. The thought keeps recurring to me, perhaps we may have in this uneven distribution a powerful instrument to use in preserving peace. Russia, the British Empire, and the United States, though they have much, are all "have nots" and must buy minerals from each other and from smaller nations. No one of them could ever hope by conquest to control all the minerals they need. If this fact is realized it should lead to frank recognition of the necessity of interdependence and

a will to conduct affairs so they may live and trade in peace.

Yet I am compelled to admit, when I think of the half-truths and misinformation that always gain acceptance as fact in the minds of both leaders and led, that World War III is more than a possibility. It is perhaps just as much of a certainty as that I shall have an automobile accident, maybe more certain. I carry insurance against accident with my car. If we as a nation could have similar insurance against the accident of another world war it would be well worth buying. I am afraid the nations of the world have neither the intelligence nor the character to postpone forever World War III.

Mr. Hotchkiss: Your regret at these facts is no less keen than my own. But no emotional desire of yours and mine can change the facts. So it is well for us to look the facts squarely in the face and form our judgments in accord with them.

World War III will arise partly out of old hatreds, partly out of new hatreds engendered by World War II, and partly because of the inevitable mistakes made in settling World War II. But the chief reason will be a combination of circumstances of aggrievement with vigorous, ruthless leadership, accompanied by the forgetting, by the present allies, of the necessity of forcefully nipping aggressive preparations in the incipient stages.

World War III will be preceded by the intensive parading of grievances—which will be real and many, ask almost any convict being punished for his crime—and by the widespread cultivating of friendships with other nations having real or fancied reasons for sympathy with the "oppressed." There will be long continued, shrewd cultivation of alliances which may cut across the alignments of World War II just as it has cut across those of World War I.

Who will attack whom I am not sufficiently wise to predict, any more that I am capable of saying when the attack will

take place. Who will be on one side and who on the other no one can tell us. It will not be decided by present leaders, but by the unknown leaders of a generation—we hope it is longer—from now.

Two things seem most probable for World War III. One is that the U. S. will not be the attacker, but will again wait until it is openly attacked before going to war. The other is that the aggressors of World War III will profit by the mistakes of I and II in which the U. S. was allowed ample time to muster its strength and come in to give the finishing blows.

Consequently it is very likely that the opening blow of World War III will be struck at the United States, suddenly and without warning, to cripple its ability to bring its force to bear. In these days land invasion is not necessary to accomplish this. A few thousand giant bombers, rocket propelled or whatever is the last word at the time, coming across the north polar area with no warning, could easily destroy the locks at Sault Ste Marie through which practically all our iron ore must pass. Such an attack could put our steel industry out of commission for a year. They could cripple our greatest steel plants and other great potential war factories before we knew there was a war on, just as Pearl Harbor happened. If our army is then in the condition it was at the time the war started in Europe in '39 there would be no chance of our building the armament to equip the armies necessary to be effective against the super-blitzkrieg that will inaugurate World War III.

Perhaps the word blitzkrieg is unfortunate in that it may be misinterpreted to imply that I believe that Germany will necessarily be the aggressor a third time. I make no such implication. I am not at all sure what nation or coalition of nations will be the aggressor. I do believe strongly however that the aggressors will attack the U. S. first, and with no warning.

Here I think I can hear suggestions that such an attack from either one of the Axis nations will be easily prevented. Just deny them all oil, or forbid them to have any airplanes, or destroy their steel industries and never permit them to rebuild them. These are defensive measures and I am not sure that if we did these things we would have the wisdom and hardness to keep them effective. In modern war the advantage is all with the attacker. He chooses the time and place, and the defenders can never be certain of either so as to concentrate adequate forces to meet him.

The only *sure* defensive tactic that I know of is the one Jehovah enjoined Saul to carry out, referred to on page 18, to kill the enemy man, woman and child. Brutal as the world is I cannot imagine any victor in these days doing so complete a job as this. But even if all the Axis citizens were killed off it would only prevent *their* decendents from waging war again. It wouldn't prevent other nations from starting war in the future.

Defensive repression of the defeated enemy will undoubtedly follow this war. But repressive regulations are always subject to evasions. Such regulations, after the last war, were readily evaded. The 100,000 men allowed for a German army were carefully selected and thoroughly trained to be 100,000 competent officers. Marching clubs of civilians were formed, and went on "hikes" that trained them for military maneuvers. Boys were gathered into youth groups and trained, both physically and mentally, to be soldiers.

The harsher the restrictions and the more unjust they are felt to be the greater the determination to evade them. If after this war the Germans are forbidden to have any air planes, either civil or military, arrangements could be made with some friendly nation to send Germans there to be trained in flying, as they were sent to Russia after World War I. If they were forbidden to do this as Germans they

could become citizens of the friendly foreign country—in their own minds intending this as a temporary citizenship only—and the regulations evaded, and a German force of military flyers trained, ready for the time when we soften and permit them to have planes.

And yet there will be repressions set up to prevent the Axis nations from preparing for another war. My hope is that they will be frankly stated as punishments fitted to a crime, and that they will be enforced relentlessly for the specified time however long it may be. High placed German generals have stated their policy to weaken their neighbors and enemies so that they will be able to win in World War III. Gen. Stuelpnagel is quoted in the New York Times as saying "With the war booty which we have accumulated, the enfeebling of two generations of the manpower of our neighbors, and the destruction of their industry, we shall be better placed to conquer twenty five years from now than we were in 1939."

Though at least partially successful attempts will surely be made to evade whatever repressions are set up I believe that certain ones are necessary. They should be selected most carefully to serve two purposes, to prevent the Germans and Japanese from acquiring sufficient war power, and to avoid on the other hand, as much as possible, repressive measures that will invade the personal affairs of citizens and so prepare them to be willing followers of rabble rousing leaders who will appeal to their resentment of such personal interference.

As a nation we have the amiable weaknesses of being idealists, of sympathizing with the oppressed and downtrodden, of generosity to those who suffer. I think we are a bit proud of these weaknesses—we like ourselves better because we have them. But we must not forget that these weaknesses may lead us into trouble if we do not temper them with realistic judgment. We need to learn to recognize

ourselves for what we are, "to acknowledge limitations without losing courage, and to build our lives on what we are rather than what it is pleasant to dream ourselves to be."

If we are realistic we will recognize that the preservation of the peace in the future cannot be accomplished by setting up some inspired formula developed by an international conference. The preservation of peace will be a continuing process of day to day, year to year, meeting current problems that create differences of opinion and inspire jealousies, and settling them justly and fairly and unselfishly. It will mean the quick, resolute, forceful "spanking" of a recalcitrant nation on proper occasion. The more effective the machinery that is set up to effect the solution of these future difficulties currently the longer will World War III be postponed.

Force, as an agency for keeping the world out of another world wide conflict, must be available and must be used promptly to be effective. To be available for prompt use force must be in continued existence in sufficient quantity to meet the current need. If force is not used promptly and effectively we shall have taken the first step toward World War III.

It is in connection with the use of force that mineral resources enter the picture. Wars cannot be fought successfully without an adequate supply of mineral resources. Without ample supplies of oil and the metals, manpower would be helpless cannon fodder, no matter what numbers were put in the war. Ample supplies of necessary materials other than minerals are equally essential, but since we are concerning ourselves in this discussion with minerals only, the other materials will not be considered.

On page 107 the wartime demands for metals are compared with the peacetime demands. War demands the greatest possible expansion of oil and metal production and use. For many minerals of the utmost essential nature we are

dependent wholly or in part on supplies that must come to us from overseas. If we are the first nation attacked in the next war our means of bringing these minerals in from abroad would be a vital point of industrial vulnerability subject to attack. Submarines stopped enough of our imports in both world wars to cause serious handicap and real alarm. In their raiding of the Carribean in this war they were not at all indiscriminate. They picked ships to sink that bore loads we most needed. Amongst others they concentrated on oil tankers and ships loaded with Surinam bauxite. We said Germany should not have any more submarines after World War I. Will we say so again after World War II? And if so will we get the same result?

Furthermore it has not yet been certainly determined whether sea power, or air power, or both jointly, will control the shipping lanes in World War III. Certainly an aggressor nation will make the strongest possible effort to control the sea, and will bend every bit of inventive and scientific genius available to devise new and better ways of doing so. We have been fortunate in the last war and the present one to be on the side that dominated the seas and so have been able to bring in much of the mineral supplies we needed. Whether we shall be so lucky in World War III is so far from certain that we should take every precaution to insure ourselves a sufficient mineral supply on hand to last us through any probable time that another war may last.

On page 156 I referred to the probable sources of our iron ore by the time of another war. If the present war were to demand our easily available open pit iron ore for three more years at present rates we would find grave difficulty if not a definite impossibility to supply our steel industry for the duration of World War II. We will be in quite a different situation by any probable date for World War III. Our domestic ores will then have to come very largely from great concentrating plants, not yet even

designed, which will have to use concentrating methods not yet devised. It will require many years of intense basic scientific research, then a long time of experiment to apply the processes commercially before all these great plants necessary for manufacturing iron ore can be built and put into successful operation.

It will be commercially unprofitable and economically unjustifiable to build such plants in numbers sufficient to supply the doubled demand that war will make on iron ore supply. Consequently iron ore producers can build only the capacity that will supply peace demands. When war comes again it will not be possible at that time to put some more big power shovels into waiting ore deposits and get our doubled war supply as it has been in World War II.

The cheapest and wisest solution—the best anti-war and anti-defeat insurance policy we can take out—will be to build up, at various strategic locations, stockpiles of ore sufficient to provide the added amounts that war would demand.

If World War II ends with 1945 we will have used during the five years of war a total of over 450 million tons of Lake Superior ore. About half of this would be the extra-normal production occasioned by war demands. If we were to be generous in our estimate of the needs of the next war we could figure that we might need 300 million tons in addition to current production in those years. This 300 million tons could be put in stockpiles at proper strategic locations and suitably guarded until the next war for a total outlay of considerably less than two billion dollars. It would be quite well worth while to invest the required amount as insurance that we would have ample supplies of iron ore available for our defence.

An accumulation of such a quantity of ore could be made safely over a period of at least a decade, probably more, as world conditions warranted. It could be accumulated more

rapidly in depression years and less rapidly in boom years, and so make an effective balance wheel for employment. The labor of mining and transportation would be done in peacetime, not at the high costs of wartime conditions. When and if war came the demands on our manpower for mining and transportation and the demands on an over burdened transportation system would be greatly reduced from what they otherwise would be.

The ideal preparation for war would be to have the ships, tanks, planes, artillery and all other supplies ready at any time. But this is impossible because designs change rapidly and to fight a war successfully requires the latest and best in equipment. So it is impossible to make up war time armament much in advance of the time it must be used.

The thing we can do is to insure plenty of the necessary mineral materials with which to make ourselves plenty of up to date equipment when the need arises. Studies should be made as to the desirability of doing such part of the work on these materials as might hasten actual manufacture when the war came. It might be desirable to have part or even all of the 300 million tons of iron ore made into pig iron or even into steel ingots and stored in that partly completed form. This could be done most cheaply by using the capacity of iron and steel furnaces in depression times when they might otherwise be idle, and would serve as a balance wheel for labor and industry.

Every ton of iron and steel scrap the government may possess at the close of the war, that can with reasonable cheapness be so disposed of, should go into a war stockpile, not a ton of such scrap should be sold. Every ton of copper, lead, zinc, manganese ore, chromite ore and other war mineral resources that belongs to the government should go into a stockpile to be added to later to insure us against need in the time of the next war.

Procedures similar to that suggested for iron ore should

be used for all of the minerals which we produce or must bring in from outside our continental boundaries. Sufficient stocks of imperishable materials to enable us to fill our war needs should be acquired and stored in the most strategically safe and desirable locations that our military staffs could select.

An insurance policy of this kind would be of incalculable value if and when World War III begins. The kinds of material to be stockpiled and their quantities should be determined by most careful study in which the best military and industrial minds should participate. Rough estimates made without extensive study would indicate that not to exceed five billion dollars would provide us such an insurance policy. The present war is costing the U. S. more than a quarter of a billion dollars a day. If the provision of mineral stockpiles adequate to win World War III were to shorten that war by only one month the investment of 5 billion dollars would yield a handsome financial profit. If it sufficed to give us such a degree of preparedness that it postponed World War III indefinitely the financial profit would be incalculable.

But the financial profit would be the small part of the benefit if the last result could be so cheaply bought. The greater benefit would be that by such intelligent handling of our mineral resources we should have secured for your grandchildren and mine the possibil ty that their lives might be lived to the end under the happier conditions of world peace.

Mr. President: In accordance with our custom we will all be on deck tomorrow morning at 5 o'clock to see the locks at Sault Ste Marie. I happen to know that the possibility of damage to these locks by air attack worried responsible officials in Washington in the early days of this war. It will be interesting tomorrow to look over the locks and imagine how long it would take an air-borne force of 5000 men to

destroy them, and also to speculate on the effect of a thousand planes dropping 10 ton blockbusters.

This will make an appropriate conclusion to our forum on mineral resources. I wish every citizen could have sat with us and learned what we have learned. Hotchkiss you have our deep thanks.

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